

**ISSUES IN ACCESS PRICING:  
INVESTMENT AND THE FAIR RATE OF RETURN  
FOR A REGULATED MONOPOLY**

A thesis submitted for the degree  
of Doctor of Philosophy in  
The Australian National University

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November 2003

Except where otherwise acknowledged in the text, this thesis represents my own original research.

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November 2003



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## **ABBREVIATIONS**

ACCC: Australian Competition and Consumer Commission

ADC: Access Deficit Contribution

AJ: Averch-Johnson

BL Cost: Backward-Looking (Historic) Cost

CLECs: Competitive Local Exchange Carriers

DSL: Digital Subscriber Loop

FCC: Federal Communications Commission

FL Costs: Forward-Looking (Replacement) Costs

ILECs: Incumbent Local Exchange Carriers

LEC: Local Exchange Carrier

NECG: Network Economics Consulting Group

PC: Productivity Commission

PSTN: Public Switched Telephone Network

ROR Regulation: Rate-of-Return Regulation

RBOCs: Regional Bell Operating Companies

TELRIC: Total Element Long-Run Incremental Cost

TPA: Trade Practices Act

TSLRIC: Total Service Long-Run Incremental Cost

UNEs: Unbundled Network Elements

USO: Universal Service Obligation

## ACKNOWLEDGEMENTS

A great many people have contributed to this thesis. First and foremost, I am extremely grateful to members of my supervisory panel, who over the years were each most generous with their time and always willing to offer excellent advice. Dr Matt Bengtson provided me with painstaking and very detailed editorial comments and technical advice on every chapter. Dr Robert Albon also read and provided extensive comments on all chapters, and made tireless efforts to ensure that I was always kept updated and informed on current issues in regulation. Dr Chris Jones provided general comments on the thesis, and particularly helpful suggestions for establishing the shareholder and general-equilibrium models used in chapters two and three.

Current and former members of the School of Economics also helped shape the ideas in the thesis. In particular, I would like to thank Mr Ben Smith, who in the course of informal discussions and seminars provided suggestions and comments that allowed me to gain a greater insight and understanding of my work; Mr Scott Austin, who provided editorial comments on Chapters 6 and 7, and who I had many discussions with about aspects of my research; and Dr Vladimir Smirnov, who provided technical advice on the proof in Chapter 5.

I am also grateful to Professor Stephen King, for his constructive suggestions as a discussant of a paper presented at the Annual PhD conference in 2002, Mr David Chapman, who provided information on the calculation of rates of return for regulated industries, and Mr Greg Cutbush, who initially stimulated my interest in the area of utility regulation.

I was able to conduct my research in part, due to the generous financial support supplied by ACCC, and the excellent research facilities supplied by the School of Economics and the ANU. I am most grateful to Staff at the Commission, in particular, Mr Joe Dimasi and Ms Katrina Huntington, who facilitated my attendance at a number of informative ACCC conferences on important issues in regulated industries. I am appreciative of the ANU for the opportunity to present ongoing research at various workshops and seminars.

I would also like to thank Staff and fellow PhD students of the School who provided invaluable support and companionship throughout the years, especially Dr Aki Asano and Mr Phong Ngo. The administration and IT staff of the Faculty of Economics and

Commerce have always been most accommodating, in particular Ms Zann Miranda, who was always wonderfully efficient and helpful in smoothing over administrative matters. Thank you to Suzy for providing me with sustenance on many late nights of research.

Finally, my deepest thanks go to my father and mother, and partner Rachel, for their loving support, and for enduring.

## ABSTRACT

Access regulation has become an important tool for promoting competition in utility industries in many countries, including Australia. A “fair” access regime aims to limit the market power of the access provider, while still guaranteeing that the firm is adequately compensated for use of its infrastructure. As a substantial proportion of the costs incurred by utilities are capital costs, the allowed fair rate of return and the method of asset valuation employed by the regulator, are crucial for determining the regulated access price. The level of the access price has been a subject of ongoing debate, and concerns have been raised about the potential impact it has on allocative, production, and dynamic efficiency. Using a number of models this thesis examines the impact that the fair rate of return and the method of asset valuation can have on allocative, production and dynamic efficiency.

The Averch and Johnson (1962) model of rate-of-return (ROR) regulation is used to examine the impact of the allowed fair rate of return on the production and allocative efficiency of the monopoly. It is illustrated that an identical outcome to ROR regulation is achieved, by providing the monopoly with the appropriate capital subsidy and subjecting it to a lump-sum tax. This equivalence result is then used to confirm and extend existing welfare results on the optimal fair rate of return established by Sheshinski (1971), Bailey (1973) and Yang and Fox (1994).

To assess the impact regulatory asset valuation has had in practice, an overview is provided of the forward-looking (FL) total element/service long-run incremental cost (TELRIC/TSLRIC)-based method that has been used to price access in US and Australian telecommunications. This suggests that claims made about below-cost rates and under-investment in the network have been exaggerated. To assess the impact of asset valuation formally, a model is established that compares the outcomes under backward-looking (BL) and FL cost regulation for an existing investment, in an industry experiencing continual technological progress. This illustrates that where both schemes allow the investor to recover costs, a constant BL cost-based price generates a better outcome for society. The superiority of BL costs is achieved without having to appeal to the investment timing and uncertainty that is central to the analysis of Guthrie, Small and Wright (2001).

Finally, to examine the impact of access regulation on dynamic and static allocative efficiency, a model is established that examines investment timing. The outcomes for a

competitive investor and a monopoly investor are examined. Similar to Gans (2001), it is found that the socially-optimal outcome is achieved by a two-part tariff, which is both static allocative and dynamically efficient. The optimal linear price for each investor is a second-best price that is neither allocatively nor dynamically efficient. The framework captures a number of important policy considerations highlighted in two Productivity Commission reports on access regulation from 2001.

# CHAPTER 1: INTRODUCTION

## 1.1 Access Pricing Issues

Over recent decades there has been significant reform across a number of countries in the treatment of utility industries like gas, electricity, telecommunications and rail. The reforms have included such things as: the structural separation of vertically-integrated monopolies; a transition from state- to privately-owned regulated monopolies; the adoption of more incentive-based or light-handed forms of regulation; and allowing entry into previously legislatively-protected markets. A common theme of many of these changes was the attempt by governments to decrease the market power of incumbent firms, and establish a framework through which sustainable competition could eventually emerge. As the Productivity Commission notes, the benefit to society from having competition between suppliers of goods and services is that it leads to “lower prices, a wider range of products and better service of customers”.<sup>1</sup>

In the network-based wholesale access market, which deals with the reticulation of services to the downstream retail market, regulators have recognised that it is difficult to induce competitive entry. This is due to persistent economies of scale and scope and the significant sunk costs that are presently associated with constructing new network segments. In the interim, to prevent an incumbent access provider from exploiting any market power it may have, regulators have stipulated terms upon which firms in downstream markets can access these “essential facilities”. Access regulation has become an important tool for assisting regulators in promoting competition in utility industries. It ensures that even where there is little or no entry in the facilities-based market, this does not preclude competition from arising in the downstream retail market.

In Australia, the importance of access regulation is well documented in the separate Productivity Commission (PC) Inquiry Reports into *Telecommunications Competition Regulation* (PC, 2001a) and the *National Access Regime* (PC, 2001b). The PC (2001a) states in its *key messages* (at page 243, Box 8.1) that “appropriately set access prices” are,

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<sup>1</sup> Productivity Commission (2001b) at page 35.



...more likely than other measures to increase efficient competition in final markets with gains, such as, lower retail prices, greater innovation and product differentiation and heightened incentives for cost cutting by the incumbent.

While the PC (2001b) notes in its *key messages* (at page XII) that:

Access regulation provides a means for businesses to use the services of 'essential' infrastructure...that is uneconomic to duplicate. Without such regulation service providers might deny access to their facilities or charge monopoly prices for their services. This could be costly for the community.

The significance of access regulation is also highlighted by the observation that in Australia, it has "a material impact on well in excess of \$50 billion of assets".<sup>2</sup>

Ideally a "fair" access regime should balance the competing interests of the access provider and the access seekers. This involves setting a regulated price for interconnection that limits the market power of the access provider, yet guarantees the access provider receives adequate compensation for use of its facility. Such a price ensures that there is not only scope for downstream market competition, but also ongoing incentives for the incumbent and potential entrants to invest in the facilities-based market. In practice though, access providers in a number of countries, including Australia, have consistently claimed that access prices are set at below-cost rates and have failed to encourage the necessary levels of investment. The PC (2001b) has acknowledged the controversy surrounding access regimes, stating (at page 35) that:

The merits of access regulation have been the subject of much debate. This is not surprising given its potential ramifications for providers of essential services, users of those services and investors in infrastructure.

#### 1.1.1 Access Pricing and Capital Costs

Access regimes still predominantly use cost-based pricing methods. Chapter 13 of the PC (2001b) outlines that a substantial proportion of the costs incurred by firms in utility industries are capital costs. For example, it maintains (at page 353) that for access providers in the Australian gas industry, "around 70 per cent of total revenue is required to fund capital costs"; and also quotes from the work of Parry (2000), who states (at page 140) that:

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<sup>2</sup> PC (2001b) at page 55. For a significantly larger figure see "Waiting for the Lights to Go Out" by Henry Ergas (*Australian Financial Review*, 23 September 2003). Ergas claims that, "decisions of Australian regulators affect more than \$120 billion of assets."

Importantly, it is the capital-related costs (return on and return of capital) that dominate the total revenue requirements for the infrastructure assets involved in access to major utilities such as electricity, gas, telecommunications and rail.

The importance of capital costs means that the **allowed fair rate of return**, and the **method of asset valuation** used by the regulator, both play a crucial role in determining the final access price. The PC notes that these two issues have become “contentious areas”.

Grout (1995) highlights the significant impact that a small change in the **allowed fair rate of return** can potentially have upon revenues earned by regulated firms in the UK. According to his analysis (at page 386, Table 16.1), at the time, a one percentage point increase in the allowed rate of return on equity across utility industries in the UK would have led to an additional £562 million of revenue being earned by these regulated firms. In Australia, two recent articles in the *Australian Financial Review* (AFR) highlight the importance of the allowed fair rate, and the opposing sides that have been taken in the debate.

In “Waiting for the Lights to Go Out” (AFR, 23 September 2003), Henry Ergas criticises Australian regulators for setting rates of return too low, leading regulated firms to under-invest in essential infrastructure. He claims that compared with Australia, “regulated rates of return in the United States are substantially more generous to investors”, and that “returns in the UK...are significantly higher once differences in market risk are taken into account.” The Chairman of the Australian Competition and Consumer Commission (ACCC), Graeme Samuels, responded to these criticisms in “ACCC Aims to Get Balance Right” (AFR, 25 September 2003). This article provides evidence that there has been significant investment in gas transmission since the introduction of the access regime, and cites a positive assessment of energy regulation in Australia from the ratings agency Moody’s. In contrast to Ergas, Moody’s finds that allowed rates of return for gas and electricity transmission in Australia are higher than those in the UK, and above the market requirements.

The debate over the **method of asset valuation** has emerged due to a recent preference by regulators for using forward-looking (FL)/current/replacement costs, instead of the traditional backward-looking (BL)/original/historical/embedded costs, to value the capital assets of the regulated firm. The adoption of FL costs appears to be based on the belief that, unlike BL costs, it removes the incentives for cost inefficiency, and provides the correct signal for potential investors to the industry. However, the FL cost standard

employed by regulators has been the subject of controversy. It is widely claimed that as regulators are now able to value existing assets on the basis of some new lower-cost technology, there is the potential for access to be under-priced. The present doubts over the use of FL cost regulation are reflected by the PC (2001b) report, which maintains (at page 366) that it has led to “considerable additional costs and uncertainty for regulated firms and access seekers alike”, and its “conceptual superiority is not often evident in these cases.”

### 1.1.2 Access Pricing and Efficiency

A key concern of access regulation is the impact it has on the efficient use of, and investment in, essential infrastructure. As in other countries, regulators and industry commentators in Australia have identified three types of efficiency that access regimes should aim to achieve — allocative efficiency, production efficiency and dynamic efficiency. For example, these efficiencies are specifically discussed in the Hilmer Report (Independent Committee of Inquiry, 1993), by the ACCC (1997) in its access pricing principles guideline issued for telecommunications, and by the Productivity Commission in its two reports on access regulation — PC (2001a,b). Additionally a number of commentators have recognised that for an access regime to maximise the benefits to society, it may need to trade-off the various types of efficiency. For example, NECG (2001a, 2001b) in its submissions to the Productivity Commission, suggests that there will be a static allocative and dynamic efficiency trade-off associated with setting the appropriate regulated access price.

There has been great deal of theoretical microeconomic analysis of the two static efficiency concepts — production and allocative efficiency. Hence, there are well-established definitions of these terms, and it is generally accepted by regulators and industry commentators that:

- **allocative efficiency** involves ensuring that resources are allocated to those producers and consumers who value them most highly;<sup>3</sup> and

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<sup>3</sup> This definition of allocative efficiency adopted by regulators and industry commentators is from the literature on welfare and public economics. It is important to recognise here that there is a very different definition in the applied econometrics literature, which examines productivity efficiency using the data envelopment analysis (DEA). As illustrated by Uri (2000), in the literature on DEA, the term “allocative efficiency” is customarily used to capture a type of production efficiency.

- **production efficiency** involves the firm producing the given level of output at the minimum cost to society.

**Dynamic efficiency** is often vaguely defined as being associated with ensuring that incentives are maintained for the access provider to innovate and invest in the essential infrastructure over time. Unlike the static efficiency concepts though, there appears to be disagreement over the precise meaning of the term. This is highlighted by “dynamic inefficiency” being used to describe instances where the investment is not undertaken immediately, and instances where it is delayed relative to some often undefined “socially-optimal” time. The inconsistency in referring to the terms dynamic efficiency or inefficiency may stem from the fact there appears to have been little formal microeconomic analysis of the concept.

## **1.2 Analysis of Access Pricing in the Thesis**

This thesis examines the issue of access pricing for a regulated monopoly. In particular, it focuses upon the fair rate of return and the method of asset valuation, and the implications this has for investment and allocative, production and dynamic efficiencies. The efficiency or welfare analysis in this thesis generally uses models where it is assumed there is no uncertainty. Consequently, this thesis does not use models that explicitly address the type of asymmetric information problems dealt with in the work of Laffont and Tirole.<sup>4</sup>

Excluding the Introduction and Conclusion, the thesis comprises six Chapters. Each contains a brief literature review in its introduction, and explores a different type of efficiency implication, or efficiency trade-off, associated with access regulation. As the results and contributions to the literature are detailed in the introduction of each Chapter, the brief structure of the thesis outlined here provides a more general overview of the particular capital cost issues and efficiency implications that are being addressed.

Chapters 2 and 3 examine the impact the allowed fair rate of return has on the monopoly, by using the Averch and Johnson (1962) model of rate-of-return (ROR) regulation. Chapter 2 looks at the issue of production efficiency under ROR regulation. It compares the capital-subsidised and ROR-regulated monopoly, and highlights a link

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<sup>4</sup> For examples of the models of regulation based on asymmetric information see Laffont and Tirole (1993).

between the behaviour of the monopoly subject to a fair rate of return and a monopoly receiving a capital subsidy. Chapter 3 uses the link established in Chapter 2 between the fair rate and capital subsidy, to assess the impact ROR regulation has on overall welfare. It examines the production and allocative efficiency trade-off associated with ROR regulation, and the properties of the optimal fair rate of return that maximises welfare.

Chapters 4 and 5 address the issue of the method of asset valuation used by the regulator. Chapter 4 contrasts the history of telecommunications regulation in the US and Australia, and describes the FL access-pricing regime known as total element/service long-run incremental cost (TELRIC/TSLRIC), that has been adopted to price interconnection to telecommunication networks in both countries. It summarises the various criticisms of the FL TELRIC/TSLRIC regulation made in the US and Australia, and looks at empirical evidence in relation to the impact it has had on network investment. Chapter 5 establishes a formal multi-period model to assess the outcomes when BL and FL cost regulation are applied to an existing investment, in an industry experiencing a constant rate of cost-decreasing technological progress. It compares the fair rate of return required for cost recovery, and the benefit to society under each access regime. As it is assumed there is no incentive to pad costs, the benefit to society is captured by measuring the levels of allocative efficiency derived from BL and FL cost regulation over a number of time periods.

Chapters 6 and 7 look at the effect regulation has on static allocative and dynamic efficiency, by employing a model that contrasts the impact access regulation has on the investment timing of a firm with an exclusive (monopoly) right to invest, and a firm facing perfect competition to undertake the investment. Chapter 6 assesses the impact of a two-part access tariff, while Chapter 7 explores the impact of a linear access price. Both Chapters also briefly consider the effect of ROR regulation. By adopting a standard for dynamic efficiency that is consistent with a definition used by the PC (2001b) for the socially-optimal investment time, the framework captures a number of important policy considerations highlighted in the PC (2001a, b) reports.

# **CHAPTER 2: RATE-OF-RETURN REGULATION AND THE CAPITAL SUBSIDY — AN EQUIVALENCE RESULT**

## **2.1 An Introduction to Rate-of-Return (ROR) Regulation**

Rate-of-Return (ROR) regulation was established in the late nineteenth century by the American judicial system. It was designed to restrict the market power of utilities — such as gas, electricity and telecommunications — while still ensuring that these firms remained financially viable. It soon became the major institution for monopoly regulation for both state and federal regulatory bodies in the US.<sup>1</sup> Although the majority of legal issues, pertaining to the manner in which ROR regulation was implemented, were settled by the mid-twentieth century,<sup>2</sup> the economic issue of whether the regime was efficient remained unresolved. Of particular concern to economists was the high administrative cost associated with ROR regulation, and the incentives it provided for inefficient investment. Despite the problems being identified in the early 1960s, the use of ROR regulation remained widespread throughout the US until the early-to-mid 1980s, at which time it was gradually phased out. In both Australia and the UK, the traditional US-style ROR regulation was never formally adopted.<sup>3</sup>

During the early 1980s there was a trend towards more incentive-based and less heavy-handed forms of regulation. This trend led regulators in the US, UK and Australia, to gradually adopt a mix of price-cap regulation for end-user prices, and benchmark regulation for the access prices to essential inputs or facilities.<sup>4</sup> In both these forms of incentive-based regulation, calculation of the fair rate of return still plays a very

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<sup>1</sup> See Chapter 8 of Berg and Tschirhart (1988) and Chapter 7 of Sherman (1989) for a historical perspective on ROR regulation in the US.

<sup>2</sup> *Federal Power Commission v. Hope Natural Gas Co.*, 320 U.S. 591, 601 (1944).

<sup>3</sup> Forsyth (1999) claims that something more akin to ROR regulation is used in some jurisdictions of Australia.

<sup>4</sup> Vogelsang (2001).

important role in determining the appropriate price cap or access price. It is for this reason that understanding the literature on ROR regulation, and its potential consequences, should still be of significance to academics and regulators today.

### 2.1.1 The Importance of Calculating a Fair Rate of Return in Price-Cap Regulation

Price-cap regulation — sometimes referred to as CPI – X or RPI – X regulation<sup>5</sup> — was first formally proposed by Littlechild (1983) as a method for regulating British Telecom,<sup>6</sup> and was adopted by the UK government in 1984.<sup>7</sup> Seen as a more light-handed and incentive-based form of regulation, it was soon adopted by regulators in Australia, Europe and the US, to regulate end-user prices for a number of utility industries.<sup>8</sup> Estimation of the fair rate of return though is still necessary in implementing price-cap regulation. In particular, the fair rate of return, or cost of capital estimate, is still used to update or reset the so-called ‘X’ term in the price cap.<sup>9</sup> Armstrong, Cowan and Vickers (1994) highlight the importance of calculating a fair rate at page 183:

At first sight it might seem strange to emphasize the role of the cost of capital and the asset base when one of the objectives of the RPI – X system is to escape the well-known inefficiencies of rate-of-return regulation. But each regulator has the duty to ensure the firm can finance its operations, and it is clear that regulators pay close attention to these issues when setting X and K factors.

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<sup>5</sup> Sometimes the term “K” is added to RPI – X and CPI – X regulation. This term reflects the fact that a certain portion of the costs that increase over time should be passed onto the consumers. RPI – X + K regulation is particularly relevant for water reticulation systems, where the costs of maintaining minimum quality standards for water appear to have increased significantly over time.

<sup>6</sup> Price-cap regulation derives its theoretical origins from the papers of Baumol (1967) and Vogelsang and Finsinger (1979).

<sup>7</sup> Vogelsang (2001) outlines that price-cap regulation was first used in the US to regulate Michigan Bell between 1980 and 1983.

<sup>8</sup> Rohlfs (1996) points out that in the US, the Federal Communications Commission (FCC) estimated that between 1990-3 the gain to consumers from the transition to price-cap regulation of AT&T was as high as US\$1.8 billion.

<sup>9</sup> In practice, calculation of the cost of capital appears crucial for resetting the ‘X’ term in such industries as gas and electricity, but less important for resetting the ‘X’ in the telecommunications industry. In the telecommunications industry, because of the rapid rate of technological progress, the change in total factor productivity appears to be the most important piece of information for resetting X.

### 2.1.2 The Importance of the Fair Rate in Benchmark Regulation

With the break-up of many vertically-integrated utility monopolies, and the lifting of artificial barriers to entry throughout the US, UK and Australia, access to essential facilities by downstream firms has become an important issue. In determining the appropriate regulated access price that encourages both efficient use of, and investment in such essential infrastructures as gas, electricity and telecommunications networks, regulators have generally adopted some form of benchmark regulation. That is, access to the essential facility has been priced using some estimate of the long-run incremental cost associated with providing access.<sup>10</sup> As capital is the most significant portion of the overall costs in these industries, the allowed fair rate has subsequently become a key component in calculating the regulated access price.

In Australia, the importance of the fair rate of return in setting the regulated access prices has been reflected in the Productivity Commission (2001b) report, *Review of the National Access Regime*.<sup>11</sup> The Government, in an interim response to this report, has largely endorsed the core recommendations made by the Productivity Commission.<sup>12</sup> In particular, the Government has agreed to include pricing principles in Part IIIA of the *Trade Practices Act 1974*, one of which stipulates that the Australian Competition and Consumer Commission (ACCC) must have regard to setting regulated access prices that should “include a return on investment commensurate with the regulatory and commercial risks involved.”<sup>13</sup>

### 2.1.3 The Literature on ROR Regulation

Averch and Johnson (AJ, 1962) were responsible for the first theoretical model to analyse ROR regulation. Their paper showed that if the regulator sets a fair rate of return less than the monopoly rate of return, but higher than the normal rate of return on

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<sup>10</sup> For example, in Australia and the US, telecommunication regulators have adopted the forward-looking total element/service long-run incremental cost method of pricing known as TELRIC/TSLRIC. These access prices are examined in greater detail in Chapter 4.

<sup>11</sup> See in particular Chapters 4, 11, 12 and 13.

<sup>12</sup> The report, *Government Response to Productivity Commission Report on the Review of the National Access Regime* is available online at <http://www.treasurer.gov.au/tsr/content/publications/NationalAccessRegime.asp>

<sup>13</sup> See the Government response to Recommendation 6.3 in the *Government Response to Productivity Commission Report on the Review of the National Access Regime*.



capital, the firm has an incentive to engage in inefficient over-capitalisation in producing any given level of output. The significance of their paper is not only highlighted by the many papers it has spawned clarifying and extending their results, but also the fact that the inefficient over-capitalisation resulting from their model is now commonly referred to as the Averch-Johnson Effect or AJ Effect.

While AJ provided the first theoretical exposition of the cost inefficiencies that could potentially occur under ROR regulation, not long after their seminal piece two other papers emerged by Wellisz (1963) and Westfield (1965). While both authors found the same inefficient over-capitalisation as in the AJ model, they also raised other efficiency concerns in relation to ROR regulation. Wellisz highlighted that ROR regulation provided natural gas pipeline companies with the incentive to distort the efficient peak and off-peak prices.<sup>14</sup> Westfield meanwhile examined the potential for electricity utilities to purchase capital equipment at inflated prices when subject to ROR regulation, and was the first to address the more serious form of production inefficiency, the potential for capital waste or gold plating to occur under ROR regulation.<sup>15</sup>

Throughout the late 1960s to the early 1970s, much of the academic literature on ROR regulation was preoccupied with criticising or clarifying the results and implications of the model established in the AJ paper. For example:

- Takayama (1969) used mathematical techniques to highlight the results of the AJ model;
- Zajac (1970) provided a graphic exposition of the AJ model, which confirmed many of Takayama's results by mapping the impact of the regulatory constraint into an input-space diagram;<sup>16</sup>
- Baumol and Klevorick (1970) combined the approaches of Takayama and Zajac to assess, refine and correct many of the original assertions made by AJ;
- Sheshinski (1971) and Klevorick (1971) analysed the welfare implications of ROR regulation in the AJ model; and

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<sup>14</sup> In recognition of the fact Wellisz's paper emerged only shortly after that by Averch and Johnson, Kahn (1988) refers to the inefficient over-capitalisation by a firm subject to ROR regulation as an example of the AJW effect.

<sup>15</sup> Sherman (1988) provides a detailed analysis and discussion of the work by Westfield (1965). Sherman also advocates the benefits of using the Westfield model over the more popular AJ model.

<sup>16</sup> See Train (1991) Chapter 1 for another excellent graphic exposition of the AJ model of ROR regulation in the input space.

- McNicol (1973) examined the comparative static properties of the AJ model.

Arguably, Bailey (1973) provides the most comprehensive analysis of the AJ model, in her book titled *Economic Theory of the Regulatory Constraint*. In this work she not only further examined and refined the results of the papers outlined above, but also provided some of the first simple extensions to the AJ model.

While a number of papers in the 1970s attempted to test empirically, whether ROR-regulated firms over-capitalised in production,<sup>17</sup> the majority of the analysis from the 1970s to the late 1980s, centred on making extensions to the AJ model. In particular, analysts were keen to assess whether the AJ effect would remain after such things as non-linear pricing,<sup>18</sup> a regulatory lag,<sup>19</sup> uncertainty,<sup>20</sup> and dynamic considerations,<sup>21</sup> were incorporated into the AJ framework. The majority of these papers found that the AJ effect would still arise, although the level of the inefficient over-capitalisation was generally found to decrease.

With the advent of price-cap regulation, analysis of the AJ model of ROR regulation gradually began to subside during the 1990s. However, even over the last decade there have still been a number of papers that have made important contributions to the AJ model by extending and analysing their results. For example:

- Sherman (1992) and Blank (1996) both examined the issue of capital waste or gold plating. Blank proved that in order for gold plating to arise, it had to be the case that either the marginal product of capital was less than zero, or that the revenue function was non-concave. As the AJ model of ROR regulation assumed a positive marginal product of capital and a strictly concave revenue function, Blank effectively showed

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<sup>17</sup> For empirical papers that support the hypothesis of over-capitalisation under ROR regulation see Spann (1974), Courville (1974) and Petersen (1975). For a paper finding evidence of under-capitalisation see Baron and Taggart (1977).

<sup>18</sup> Crew and Kleindorfer (1971), Bailey (1973) and Waverman (1975), all examine the effect of ROR regulation on a peak-load pricing scheme, while Sherman and Visscher (1982) examine the effect of ROR regulation when two-part tariffs are being used.

<sup>19</sup> Bailey and Coleman (1971).

<sup>20</sup> Peles and Stein (1976) and Das (1980).

<sup>21</sup> Bawa and Sibley (1980) and Logan, Masson and Reynolds (1989).

once and for all, that it was an inappropriate model for considering the issue of pure capital waste;<sup>22</sup> and

- Yang and Fox (YF, 1994) incorporated a property tax — i.e. a tax on the capital assets of the firm — into the AJ model of ROR regulation.<sup>23</sup> By analysing the effects of the introduction of this capital tax, they showed amongst other things that:
  - changing the capital tax had exactly the same impact on the firm’s capital, labour, price, output and profits, as changing the regulated fair rate; and
  - increasing the level of the capital tax could potentially increase welfare.

In light of the latter of these two results the authors contended (at page 59) that, “this contradicts the long-established belief that a lower (or no) tax is preferred to a higher tax rate in maximising welfare.”

In relation to the analysis of ROR regulation done in this and the following Chapter, the results of the YF paper are of particular interest.

#### 2.1.4 The Results and Contributions of the Chapter

Given the large body of literature over the past four decades commenting on, criticising and extending the results of the AJ model, it is surprising that there never appears to have been any definitive recognition of the similarity between the behaviour of the ROR-regulated monopoly and the monopoly receiving a capital subsidy. This Chapter contributes to the academic literature by highlighting the previously unrecognised link that exists between the capital subsidy and fair rate of return. From the equivalence result a number of important theoretical and practical implications are derived, and an alternative model of ROR regulation is developed.

To establish the link between the monopoly receiving the capital subsidy and the ROR-regulated monopoly in the AJ model, the Chapter is structured in the following manner. Section 2.2 examines the behaviour of an unregulated monopoly and illustrates that compared to a competitive market, the firm under-invests. Sections 2.3 and 2.4 show that if capital is a normal input, this problem can be somewhat alleviated by either,

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<sup>22</sup> Zajac (1972) and Bailey (1973) already established that capital waste could not occur under the AJ model. However, neither offered a clear explanation for why the result emerged.

<sup>23</sup> Bailey (1973) page 99–101 originally discussed the invariance properties of a property tax, but did not go on to formalise any of her results.

providing the monopoly with a capital subsidy, or using ROR regulation. However, a problem with each scheme is that it leads to inefficient resource use, as the monopoly over-capitalises in production. Section 2.5 emphasises the similarity between the two regimes, by deriving an equivalent capital subsidy that leads to the capital-subsidised and ROR-regulated monopoly employing an identical input mix. It also explores some theoretical and policy implications of the equivalence result. Section 2.6 uses this link established between the fair rate and capital subsidy, to develop an alternative model of ROR regulation with a shareholder and manager. It yields exactly the same pattern of inefficient over-capitalisation as in the AJ model, and derives a formula that expresses the equivalent capital subsidy  $s$  for any given fair rate  $f$  set by the regulator. Section 2.7 concludes the Chapter.

## 2.2 The Unregulated Monopoly

This Section initially sets up the assumptions that are used throughout the course of the Chapter to evaluate the effects of ROR regulation and an input subsidy on capital on the monopoly. It then proceeds to examine the input choice and overall level of production for an unregulated monopoly. This highlights the familiar result that compared to the outcome in a competitive industry, the unregulated monopoly supplies a lower level of output. While this leads to allocative inefficiency, the input-space diagrams illustrate that the unregulated monopoly will be efficient in producing the level of output it chooses to supply.

### 2.2.1 The Assumptions of the Model

As in Averch and Johnson (AJ, 1962) and Westfield (1965), the analysis in this Chapter uses a simple static model of production. To establish their framework, it is assumed here that:

- the monopoly is a single-product firm that produces the level of output  $q$  using the two inputs capital  $k$  and labour  $n$  (i.e.  $q = h(n, k)$ );
- capital is purchased from a competitive factor market at price  $p_k$  per unit, and to simplify the analysis further  $p_k$  is set equal to 1.<sup>24</sup> It is employed during the initial period, time 0, and has an infinite lifespan;<sup>25</sup>
- to purchase the capital stock the firm raises financial capital at time 0. It does this by issuing financial instruments that it repays in each successive time period  $1 \dots \infty$  at the constant competitive market determined risk-free interest rate  $r$ ;
- labour is purchased from a competitive factor market at price  $w$  per unit. At each time period  $1 \dots \infty$  the same amount of labour is combined with the capital installed at time 0 to produce the same given level of output;
- the production function of the firm  $h(n, k)$  exhibits technology such that  $\partial h / \partial n, \partial h / \partial k > 0$ ,  $\partial^2 h / \partial n^2, \partial^2 h / \partial k^2 < 0$ , and  $\partial^2 h / \partial k \partial n = \partial^2 h / \partial n \partial k > 0$ ;<sup>26</sup>

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<sup>24</sup> Setting the acquisition cost per unit of capital equal to one is consistent with the approach used in the AJ framework. See Westfield (1965), Bailey (1973) and Yang and Fox (1994), for examples of the AJ model where the acquisition cost per unit of capital is not set equal to one.

<sup>25</sup> This is consistent with the assumption explicitly stated by Westfield (1965).

- to supply a positive quantity of output the firm must have positive amounts of both capital and labour, otherwise  $q = h(n, 0) = h(0, k) = 0$ ;
- the production functions  $h(\cdot)$  satisfies the Inada conditions so,  $\lim_{k \rightarrow 0} \partial h / \partial k = \infty$ ,  $\lim_{n \rightarrow 0} \partial h / \partial n = \infty$ ,  $\lim_{k \rightarrow \infty} \partial h / \partial k = 0$  and  $\lim_{n \rightarrow \infty} \partial h / \partial n = 0$ ;
- all production is consumed, and the level of demand remains constant during each period  $1 \dots \infty$ ;
- total revenue of the firm is  $R(q) = p(q) \cdot q$ , which is a strictly concave function;<sup>27</sup> and
- there is no uncertainty and no change in technology or the quality of inputs.

Unless otherwise stated it should be presumed that these assumptions hold throughout the course of the analysis in this Chapter.

### 2.2.2 Maximising Profit for the Unregulated Monopoly

The unregulated monopoly employs an amount of capital at time 0 and an amount of labour in each successive time period  $1 \dots \infty$ , in order to maximise the present value of the future net income streams (*NPV*) that it receives.

$$\max_{n,k} NPV = \sum_{t=1}^{\infty} \frac{p(h(n,k))h(n,k) - wn}{(1+r)^t} - k \quad (2.2.1)$$

Using the assumptions, all potential dynamic influences can be ruled out, and as in Westfield (1965) the above expression can be simplified for the annual level of economic profit  $\pi$ . That is,

$$\begin{aligned} NPV &= \left[ p(h(n,k))h(n,k) - wn \right] \sum_{t=1}^{\infty} \frac{1}{(1+r)^t} - k \\ &= \frac{p(h(n,k))h(n,k) - wn}{r} - k \\ \Rightarrow \pi &= r \cdot NPV = p(h(n,k))h(n,k) - wn - rk \end{aligned}$$

---

<sup>26</sup> These assumptions imply that there is substitutability in the input choice, which means that input distortions will occur when the monopoly is given an input subsidy on capital or subject to ROR regulation.

<sup>27</sup> Blank (1996) shows that the assumption that the revenue function is concave and the marginal products are strictly positive, rules out any possibility of the monopoly engaging in pure capital waste or gold plating when it is subject to ROR regulation. For a model that incorporates the potential for gold plating see Kennedy (1977).

Therefore, the monopoly will choose to employ a level of labour and capital to,

$$\max_{n,k} \pi = p(h(n,k))h(n,k) - wn - rk \quad (2.2.2)$$

The first-order conditions (FOCs) from maximising the level of annual profit are,

$$\frac{\partial \pi}{\partial n} = \left( \frac{\partial p}{\partial h} h(n,k) + p(h(n,k)) \right) \frac{\partial h}{\partial n} - w = 0$$

$$\frac{\partial \pi}{\partial k} = \left( \frac{\partial p}{\partial h} h(n,k) + p(h(n,k)) \right) \frac{\partial h}{\partial k} - r = 0$$

As  $\partial h/\partial n$  and  $\partial h/\partial k$  denote respectively the marginal product of capital ( $MP_k$ ) and the marginal product of labour ( $MP_n$ ), and the bracketed term in both equations is the marginal revenue of production ( $MR$ ), the above can be simplified, then solved to give

$$MR.MP_n = w \quad (2.2.3a)$$

$$MR.MP_k = r \quad (2.2.3b)$$

Denoting the unregulated monopoly outcome by subscript  $m$ , the above two conditions simultaneously determine the amount of physical capital  $k_m$  employed by the firm at time 0, and the amount of labour  $n_m$  employed at each time period  $t = 1, \dots, \infty$ . Given this input choice, the monopoly produces  $q_m$  units of output in each period to maximise its level of annual profit  $\pi_m$ .

Equations (2.2.3a) and (2.2.3b) can also be used to derive the familiar condition that an unregulated monopoly continues to produce until marginal revenue is equal to marginal cost, and to show that an unregulated monopoly is economically efficient in producing output  $q_m$ .

By rearranging equations (2.2.3a) and (2.2.3b) in terms of the marginal revenue of production and then equating the respective expressions, yields the familiar relationship between the marginal revenue and marginal cost of production ( $MC_e$ ) for an unregulated firm. That is,

$$MR(q_m) = \frac{w}{MP_n(n_m, k_m)} = \frac{r}{MP_k(n_m, k_m)} = MC_e(q_m) \quad (2.2.4)$$

Due to its market power, the unregulated monopoly has an incentive to under-invest and supplies a lower level of output than a competitive firm. While this results in some form of allocative inefficiency, the unregulated monopoly still uses an efficient input mix in producing output  $q_m$ . This is illustrated by dividing equation (2.2.3a) by (2.2.3b), which

yields the familiar condition that the ratio of the marginal products is equal to the ratio of the exogenously and competitively-determined factor prices.

$$MP_n/MP_k = w/r \quad (2.2.5)$$

### 2.2.3 Illustrating the Unregulated Monopoly Outcome in the Input-Space Diagram

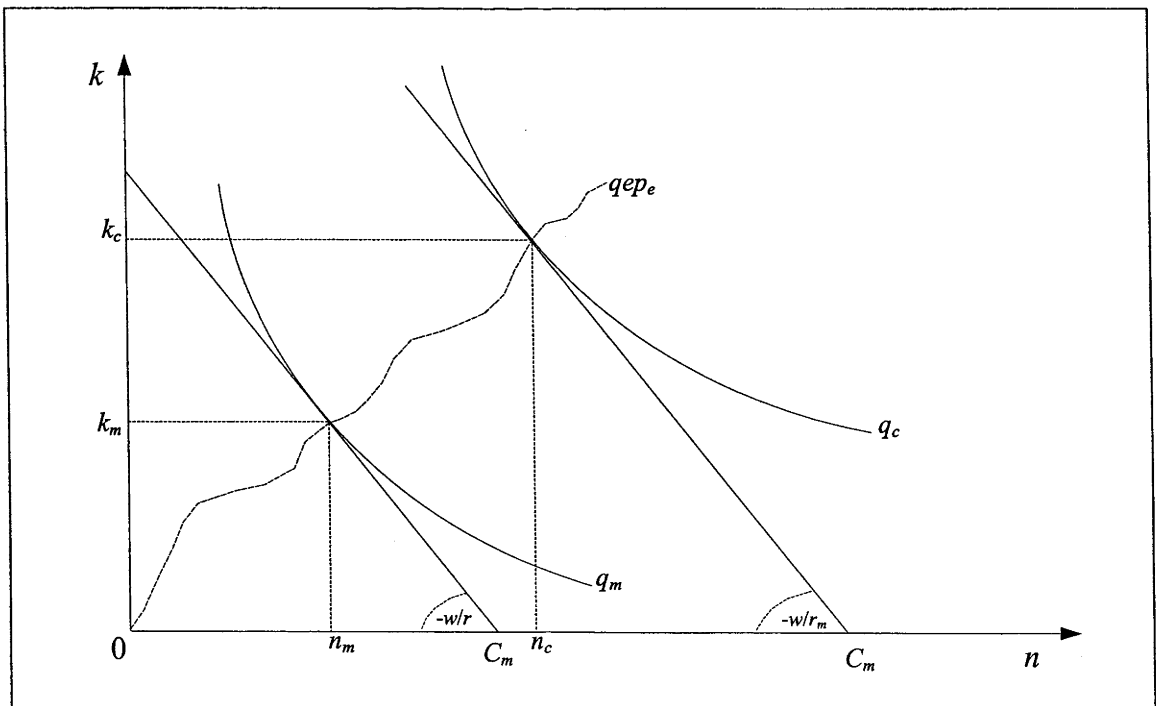
The results of the previous section are illustrated and described in the following input-space diagrams of Figure 2.2.1 and Figure 2.2.2.

Denoting the respective outcomes for the unregulated monopoly and the competitive industry by subscripts  $m$  and  $c$ , Figure 2.2.1 shows that where capital and labour are normal factors of production, compared to the outcome in the competitive industry, the unregulated monopoly:

- under-invests in capital at time 0 (i.e.  $k_m < k_c$ );
- employs less labour in each period  $t = 1, \dots, \infty$  (i.e.  $n_m < n_c$ ); and
- produces a lower level of output (i.e.  $q_m < q_c$ ).

While the allocative inefficiency created by the monopoly cannot be captured in the input space, it is possible to show in the input-space diagram that the unregulated monopoly is still efficient in its production of output  $q_m$ .

**FIGURE 2.2.1 THE UNREGULATED MONOPOLY AND COMPETITIVE MARKET OUTCOME**

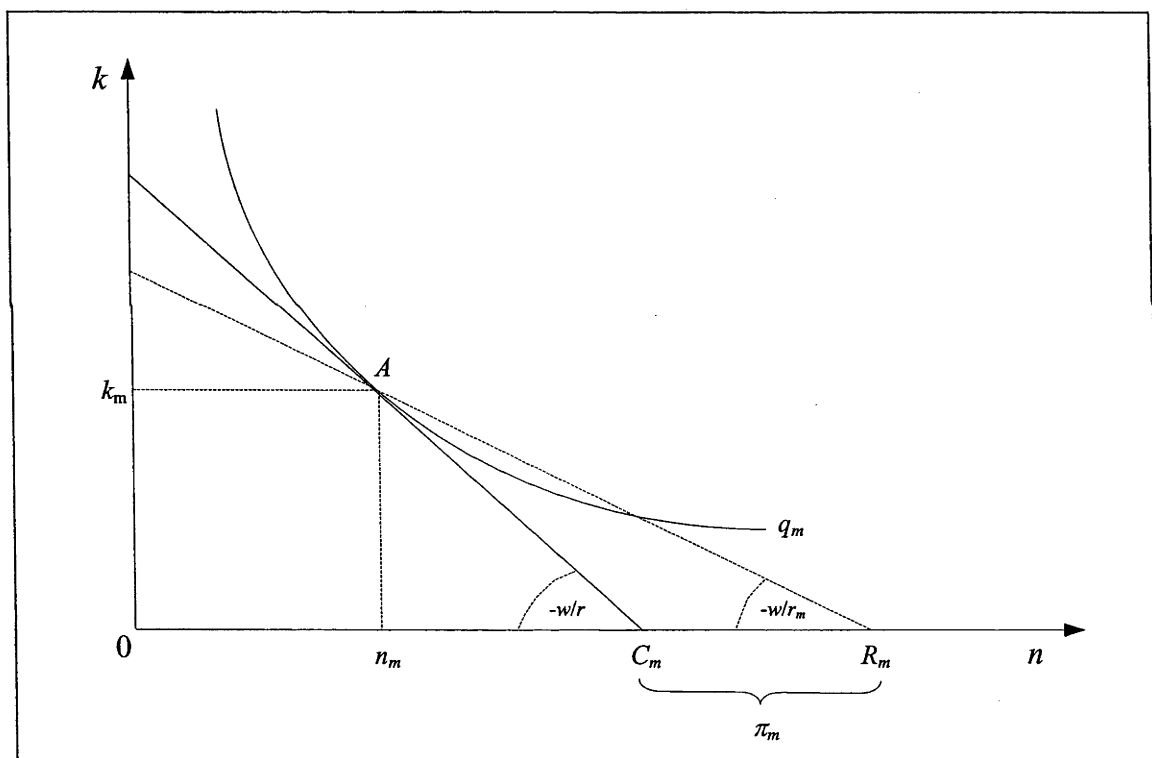




In Figure 2.2.1, the output expansion path  $qep_e$  depicts the locus of points where the input mix used by the firm produces any given level of output at minimum cost. That is, the output expansion path represents all the points where the isocost line is tangent to the isoquant, and along this line the condition for production efficiency in equation (2.2.5) will be satisfied. As the unregulated monopoly, like the competitive firm, uses an input mix along this expansion path, it must be efficient in its production of  $q_m$ . Therefore, the overall efficient cost (in units of labour) of producing the levels of output  $q_m$  and  $q_c$ , will be denoted in the input-space diagram by  $C_m$  and  $C_c$ .<sup>28</sup>

Aside from showing the input choice and cost of production for the unregulated monopoly, it is also possible using the input-space diagram to illustrate the amount of revenue and profit that the monopoly earns. This is done in Figure 2.2.2.

**FIGURE 2.2.2 UNREGULATED MONOPOLY PROFIT IN THE INPUT SPACE**



To analyse Figure 2.2.2, it must initially be recognised that the unregulated monopoly earns an overall rate of return on its investment of,

$$r_m = \frac{\pi_m}{k_m} + r \quad (2.2.6)$$

<sup>28</sup> These can be expressed in dollar terms by multiplying through by  $w$ .

That is, the monopoly rate of return  $r_m$  is comprised of, the opportunity cost of capital  $r$ , and the monopoly rent earned on each of the  $k_m$  units of capital employed by the firm.

Hence, the line that depicts the amount of revenue earned by the unregulated monopoly will have the slope  $-w/r_m$ . As the monopoly rate of return  $r_m$  exceeds the normal rate of return on capital  $r$ , in Figure 2.2.2, the revenue line passing through the input choice  $k_m$  and  $n_m$  must be flatter than the corresponding isocost line. It is then possible to denote the overall amount of revenue earned by the unregulated monopoly (in units of labour) by  $R_m$ , and the total cost of production (in units of labour) by  $C_m$ . The profit earned by the unregulated monopoly  $\pi_m$ , is the distance between these two points.

## 2.3 The Monopoly with an Input Subsidy on Capital

If the sole aim of the government is to increase the level of capital the monopoly employs, the government could provide the firm with an input subsidy on capital. It is shown that this increases the level of capital and monopoly profit, and provided capital is a normal factor of production, also increases the overall level of output produced. However, any benefit from this increase in output will be partially offset by the firm over-capitalising in its production. The production inefficiency from using this distorted input mix is illustrated in an input-space diagram, along with the resulting revenues and costs to the firm and society.

### 2.3.1 The Profit-Maximising Monopoly with a Capital Subsidy

When the monopoly receives a per-unit input subsidy on capital  $s$ , where  $r > s > 0$ , it will choose labour and capital in order to maximise the expression,

$$\max_{n,k} \pi = p(h(n,k))h(n,k) - wn - (r-s)k, \text{ where } r > s > 0 \quad (2.3.1)$$

Deriving the FOCs from the above maximisation and solving yields

$$MR.MP_n = w \quad (2.3.2a)$$

$$MR.MP_k = r - s \quad (2.3.2b)$$

Denoting the outcome for the capital-subsidised monopoly by subscript  $s$ , the above conditions can be used to simultaneously determine the amount of capital  $k_s$  and labour  $n_s$  employed by the subsidised monopoly to produce  $q_s$  units of output. Once again the conditions can also be used to derive the relationship between marginal revenue and the private marginal cost of production faced by the monopoly receiving the input subsidy on capital ( $MC_s$ ).

$$MR(q_s) = \frac{w}{MP_n(n_s, k_s)} = \frac{r-s}{MP_k(n_s, k_s)} = MC_s(q_s) \quad (2.3.3)$$

As the marginal product of both factors is greater than zero, the marginal revenue in equation (2.3.3) is positive (i.e.  $MR > 0$ ), and the demand for the output produced by the capital-subsidised monopoly, own-price elastic.

While the amount of capital employed by the monopoly must always increase when  $r$  falls<sup>29</sup> — such that  $k_s$  is greater than  $k_m$  — what happens to output  $q_s$  depends on the impact the input subsidy has on the private marginal cost of production faced by the firm. If the input subsidy on capital results in the private marginal cost decreasing, the level of output rises, while if the marginal cost increases, the level of output falls. To assess the effect of the input subsidy on the firm's marginal cost of production, the standard proof using Young's Theorem and Shephard's Lemma is worked through below.

$$\frac{\partial MC}{\partial r} = \frac{\partial}{\partial r} \left( \frac{\partial C}{\partial q} \right) = \frac{\partial}{\partial q} \left( \frac{\partial C}{\partial r} \right) \text{ (Young's Theorem)}$$

$$\text{As } \frac{\partial C}{\partial r} = k \text{ (By Shephard's Lemma)}$$

$$\frac{\partial MC}{\partial r} = \frac{\partial k}{\partial q} \quad (2.3.4)$$

The above condition illustrates that if capital is a normal factor of production ( $\partial k / \partial q > 0$ ), an input subsidy on capital decreases the marginal cost of production ( $\partial MC / \partial r > 0$ ) and results in output increasing. In contrast, where capital is an inferior factor of production ( $\partial k / \partial q < 0$ ), the capital subsidy increases the marginal cost ( $\partial MC / \partial r < 0$ ), leading to a decrease in output. In the case where capital is neither normal nor inferior ( $\partial k / \partial q = 0$ ), the marginal cost and the level of output remain unchanged.

Ferguson (1971) provides a detailed analysis of the impact that inferior factors have on the level of output produced by a firm.<sup>30</sup> He derives general results for a firm producing a single product  $q$  with  $N$  factors of production. Applying his results to the model here, where there are only the two factors of production — capital and labour — capital will be an inferior factor if and only if,

$$MP_k \frac{\partial MP_n}{\partial n} - MP_n \frac{\partial MP_k}{\partial k} < 0 \quad (2.3.5)$$

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<sup>29</sup> The reason for this is that there is no such thing as a Giffen factor of production, as the substitution and output effects will always reinforce one another.

<sup>30</sup> Chapter 9.

Provided the expression in equation (2.3.5) is greater than zero, capital will be a normal factor of production, and the input subsidy will result in the monopoly increasing its level of output from  $q_m$ .<sup>31</sup> While this will result in some improvement in allocative efficiency, this benefit will be partially offset by the capital subsidy causing the monopoly to distort the input choice away from the economically-efficient-cost-minimising input mix. Analytically, this is demonstrated by dividing equation (2.3.2a) by (2.3.2b) to yield,

$$MP_n/MP_k = w/(r - s) > w/r \quad (2.3.6)$$

As the assumptions made about production imply that the production isoquants are convex to the origin in the input space, the above inequality reflects the fact that the firm is inefficiently over-capitalising in its production of output  $q_s$ .<sup>32</sup>

### 2.3.2 The Production Inefficiency of a Capital-Subsidised Monopoly

Ignoring any changes in allocative efficiency for now (until Chapter 3), the production inefficiency that results from using the distorted input mix associated with equation (2.3.6) to produce  $q_s$ , can be illustrated in the following input-space diagrams of Figure 2.3.1 and Figure 2.3.2.<sup>33</sup> Throughout this analysis it is assumed that the input subsidy on capital  $s$  is set at a level so that the amount produced by the subsidised monopoly  $q_s$  is strictly less than the competitive level of output  $q_c$ .

In Figure 2.3.1, if the firm used the efficient input mix to produce output  $q_s$ , it would choose an input combination coinciding with point  $A$ . That is, the firm would produce along the efficient output expansion path  $qep_e$ , and incur the minimum cost of production to society  $C_e$ . However, the input subsidy on capital results in the monopoly producing  $q_s$  with the distorted input mix coinciding with point  $B$ , and choosing an input combination along the inefficient output expansion path  $qep_d$ . While the private cost to

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<sup>31</sup> If the expression in equation (2.3.5) is equal to zero, capital is neither normal nor inferior and the input subsidy on capital has no impact upon the level of output produced by the monopoly.

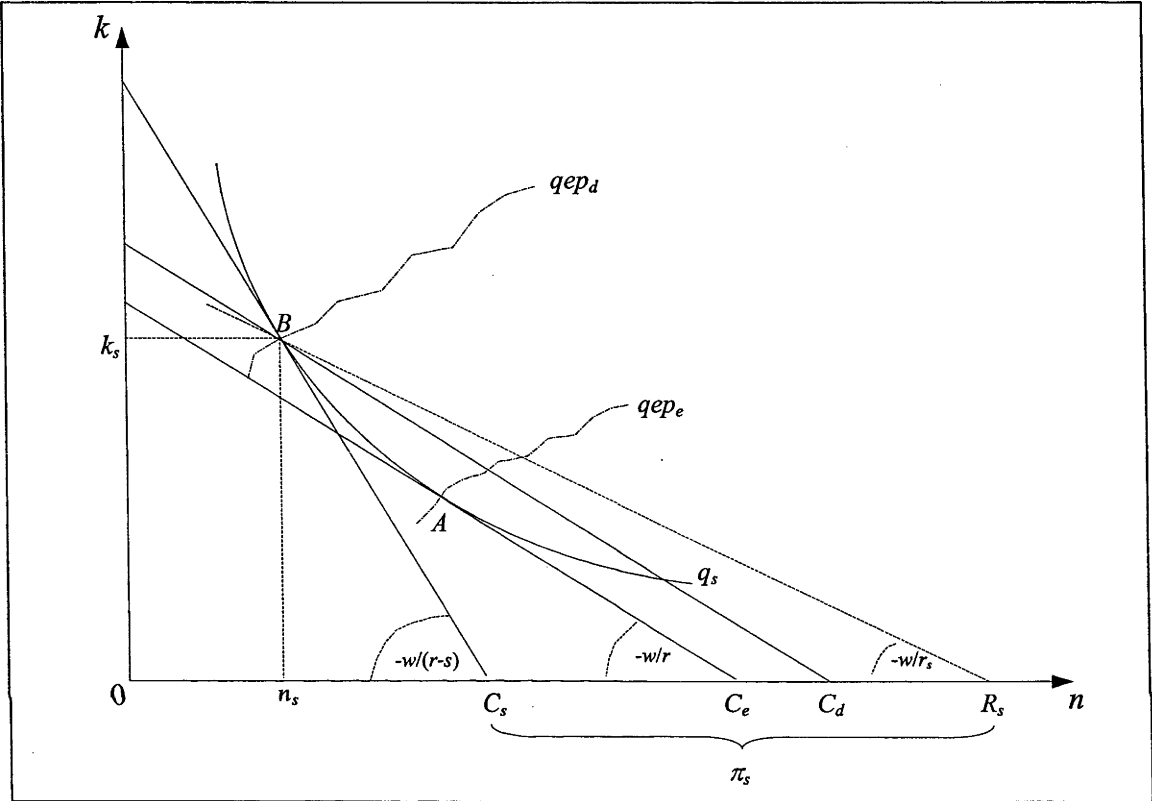
<sup>32</sup> The ability to substitute between inputs in production is responsible for the resulting production inefficiency. If the production technology did not allow for substitutability in the input choice, e.g. Leontief production technology, then there would be no such distortion occurring. In the case of Leontief production technology though, there is the potential for pure capital waste.

<sup>33</sup> The diagrammatic analysis used here to illustrate the production inefficiency that is generated from the input subsidy on capital, is similar to that used by Albon (1998), who analysed the production inefficiency resulting from having a tax on one of two inputs.



Using  $r_s$ , it is possible to depict the total amount of revenue  $R_s$  that is earned by the capital-subsidised monopoly in Figure 2.3.2. By then subtracting the total cost of production  $C_s$  from  $R_s$ , the resulting distance represents the level of profit earned by the capital-subsidised monopoly  $\pi_s$ .

FIGURE 2.3.2 REVENUE AND PROFIT FOR THE CAPITAL-SUBSIDISED MONOPOLY



## 2.4 The AJ Model of ROR Regulation of the Monopoly

In the previous Section it was observed that a capital subsidy increases the overall level of capital, profit, and — provided capital is a normal factor of production — output. While ROR regulation of the monopoly constrains the profits earned by the firm, it appears to have a similar impact upon capital and the level of output produced by the firm.

This Section briefly reproduces the key results of the Averch and Johnson (AJ, 1962) model of ROR regulation. That is, it examines the behaviour of a monopoly that experiences a decrease in profits, as a result of being subject to a regulated fair rate of return that is set in excess of the normal rate of return on capital in the market. This highlights that, as with the capital subsidy, ROR regulation leads to an increase in the level of capital employed, and provided capital is a normal input, increases the amount of output that is being produced. However, as was also the case with the capital subsidy, the ROR-regulated firm inefficiently over-capitalises in producing this increased level of output. The over-capitalisation that arises in the AJ model of ROR regulation is now commonly referred as the “Averch-Johnson Effect” or “AJ effect”. As with the previous section, an input-space diagram is used to highlight the AJ effect and the production inefficiency that arises from employing the distorted input mix.

### 2.4.1 The Constraint on the ROR-Regulated Monopoly

ROR regulation operates by allowing the firm to earn no more than what the regulator deems to be a “fair” rate of return on its existing capital assets. Thus, at any time period, total revenue minus operating expenses, total tax liabilities and depreciation charges, divided by the current value of the capital stock (also known as the “rate base”), must be less than or equal to the fair rate of return  $f$  set by the regulator. Mathematically, this constraint can be written as:

$$\frac{\text{Gross Revenue} - \text{Operating Expenses} - \text{Depreciation} - \text{Tax Liabilities}}{\text{Capital Acquisition Costs} - \text{Total Depreciation}} \leq f \quad (2.4.1)$$

To simplify the above equation so that it is consistent with the regulatory constraint that was used by Averch and Johnson, in addition to the earlier assumptions, it is assumed here that:



- the constraint is “effective”. This means, where  $r$  is the competitive rate of return in the capital market, and  $r_m$  is the rate of return on capital for an unregulated monopoly, the fair rate of return set by the regulator  $f$  must lie in the range  $r_m > f > r$ . The fair rate cannot be set equal to  $r_m$ , as this provides the regulated firm with no incentive to increase its level of investment in the industry. Further, the fair rate cannot be set equal to  $r$ , as there will then be no unique solution in the AJ model. Thus, in the AJ model, the regulator effectively overestimates the total capital costs incurred by the firm;<sup>35</sup> and
- the firm has no tax liabilities.

Combining these assumptions with those outlined in Section 2.2, in equation (2.4.1):

- the tax liability and depreciation terms can be ignored;
- gross revenue is  $p(q)q$ ;
- total operating expenses are equal to the total level of labour expenses  $wn$ ;
- the total cost of acquiring capital is equal to the total amount of capital employed by the firm  $k$ ; and
- the effectiveness of the constraint means that the inequality sign in equation (2.4.1) can be replaced with an equality sign.<sup>36</sup>

Therefore, the constraint faced by the ROR-regulated monopoly under the AJ model is,

$$\frac{p(h(n, k))h(n, k) - wn}{k} = f \quad (2.4.2)$$

#### 2.4.2 The Behaviour of the Monopoly under the AJ Model of ROR Regulation

Using the regulatory constraint outlined by equation (2.4.2), the AJ ROR-regulated monopoly employs an amount of capital and labour to,

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<sup>35</sup> The reliance on this assumption to generate all the interesting results of the AJ model has been heavily criticised by a number of commentators. For example, Baron (1989) points out that the inability of the regulator to accurately identify or target the true market rate of return on capital  $r$  implies that it must have some imperfect information about the monopoly, which has been left unexplained by Averch and Johnson.

<sup>36</sup> Takayama (1969) reached this conclusion. The intuition for this is that the regulated monopoly in the AJ model only maximises its level of profit when it earns the highest possible return on capital under the constraint, which is just the fair rate of return  $f$ .

$$\begin{aligned} \max_{n,k} \quad & p(h(n,k))h(n,k) - wn - rk \\ \text{s.t.} \quad & \frac{p(h(n,k))h(n,k) - wn}{k} = f \end{aligned} \quad (2.4.3)$$

The Lagrangian formed from this maximisation is

$$\zeta(n,k,\mu) = p(h(n,k))h(n,k) - wn - rk - \mu(p(h(n,k))h(n,k) - wn - fk)$$

and the FOCs obtained are

$$\frac{\partial \zeta}{\partial n} = \left( \frac{\partial p}{\partial h} h(n,k) + p \right) \frac{\partial h}{\partial n} - w - \mu \left[ \left( \frac{\partial p}{\partial h} h(n,k) + p \right) \frac{\partial h}{\partial n} - w \right] = 0$$

$$\frac{\partial \zeta}{\partial k} = \left( \frac{\partial p}{\partial h} h(n,k) + p \right) \frac{\partial h}{\partial k} - r - \mu \left[ \left( \frac{\partial p}{\partial h} h(n,k) + p \right) \frac{\partial h}{\partial k} - f \right] = 0$$

$$\frac{\partial \zeta}{\partial \mu} = p(h(n,k))h(n,k) - wn - fk = 0$$

Substituting the marginal revenue and marginal product terms into these conditions yields

$$MR.MP_n - w - \mu(MR.MP_n - w) = 0 \quad (2.4.4a)$$

$$MR.MP_k - r - \mu(MR.MP_k - f) = 0 \quad (2.4.4b)$$

$$p(h(n,k))h(n,k) - wn - fk = 0 \quad (2.4.4c)$$

Using subscript  $R$  to denote the outcome for the ROR-regulated monopoly,  $k_R$  and  $n_R$  are the amount of each input used to produce the profit-maximising level of output  $q_R$ , and  $\mu^*$  is the value of the Lagrange multiplier corresponding to this input choice. The FOCs can then be rewritten as the following three identities,

$$(1 - \mu^*)MR.MP_n = (1 - \mu^*)w \quad (2.4.5a)$$

$$(1 - \mu^*)MR.MP_k = (1 - \mu^*)r + \mu^*(r - f) \quad (2.4.5b)$$

$$p(h(n_R, k_R))h(n_R, k_R) - wn_R - fk_R = 0 \quad (2.4.5c)$$

As AJ (1962), Takayama (1969) and Baumol and Klevorick (1970) each establish that the value of the lagrange multiplier is between zero and one (ie  $0 < \mu^* < 1$ ),<sup>37</sup> the first two identities can be further simplified by dividing through by  $(1 - \mu^*)$ .

$$MR.MP_n = w \quad (2.4.6a)^{38}$$

$$MR.MP_k = r - \frac{\mu^*(f - r)}{(1 - \mu^*)} = r' \quad (2.4.6b)$$

From these equations the expression derived for the marginal revenue of production is

$$MR(q_R) = \frac{w}{MP_n(n_R, k_R)} = \frac{r'}{MP_k(n_R, k_R)} = MLC(q_R) \quad (2.4.7)$$

This condition can be interpreted as requiring that the ROR-regulated monopoly continue to employ capital and labour until the marginal revenue equals the marginal cost of adding an extra unit of labour — that is the marginal labour cost of production, *MLC*. The firm does this in order to maximise the total return that is allowed on its capital assets, and subsequently the level of regulated profit  $\pi_R$ . As the marginal revenue is greater than zero here (i.e.  $MR > 0$ ), it indicates that as with the capital-subsidised monopoly, the demand for the output produced by the ROR-regulated monopoly is own-price elastic.<sup>39</sup>

As the bounds on the multiplier and the assumption about the regulated fair rate of return imply that the term  $\mu^*(f - r)/(1 - \mu^*)$  in equation (2.4.6b) is positive, the effective rental cost of capital faced by the regulated firm when employing capital  $r'$ , must be less than the true cost of capital  $r$ . Therefore, the regulator, by setting the fair rate above the normal rate of return on capital, induces the regulated firm to behave as if it is receiving an input subsidy on capital. In order to highlight further similarities between the ROR-regulated and capital-subsidised monopoly, the impact of ROR regulation on production efficiency and the level of output are assessed.

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<sup>37</sup> Takayama (1969) and Baumol and Klevorick (1970) provide a more rigorous proof for the bounds of the Lagrange multiplier than AJ (1962).

<sup>38</sup> While equation (2.4.6a) provides the same condition as (2.3.2a), it is highly unlikely that the level of labour employed in the production will be the same. The reason for this is that the change in the level of capital stock impacts upon the marginal product of labour and the marginal revenue of the monopoly.

<sup>39</sup> Train (1991) illustrates the ROR-regulated monopoly always produces in the elastic portion of demand, in Result 3 at page 50.

Dividing equation (2.4.6a) by (2.4.6b) yields the expression

$$MP_n/MP_k = w/r' > w/r \quad (2.4.8)$$

This indicates that the ROR-regulated monopoly, like the monopoly receiving an input subsidy on capital, inefficiently over-capitalises in producing the regulated level of output. This inefficient over-capitalisation that arises in this model is now commonly referred to as the AJ effect.<sup>40</sup>

Kahn (1968) believed that the inefficient over-investment in capital in the AJ model could potentially be offset by the benefits derived from the increase in production under ROR regulation. Baumol and Klevorick (1970) though, illustrated that no such benefit was guaranteed under ROR regulation. They found output would decrease in the AJ model if,

$$MP_k \frac{\partial MP_n}{\partial n} - MP_n \frac{\partial MP_n}{\partial k} > 0 \quad (2.4.9)$$

Baumol and Klevorick interpret this equation (at page 178), as stating that, the quantity of output will decrease only if capital and labour are gross substitutes in production (i.e.  $\partial MP_n/\partial k < 0$ ) and labour is “a better substitute for labour than it is for capital”. While they provide the alternative explanation that the condition in equation (2.4.9) will be satisfied if capital is a “regressive” input, it was left for Bailey (1973) to be the first to show formally, that output would only decrease in the anomalous case where capital was an inferior factor of production.<sup>41,42</sup> The outcome is illustrated here by the fact that, the condition in equation (2.4.9) that must be satisfied for output to decrease under ROR regulation, is identical to the condition in equation (2.3.5) that must be satisfied for capital to be an inferior factor of production. Therefore, as was the case with the input subsidy on capital, output will increase in the AJ model if capital is a normal factor of production.

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<sup>40</sup> Industry commentators sometimes use the terms gold plating and AJ effect interchangeably. As already outlined though, there is a clear distinction between these two terms in the academic literature. Unlike gold plating, the AJ effect refers to the case where although an inefficient input mix is used to produce output, no capital is actually being wasted. According to Sherman (1989) page 211, gold plating or capital waste represents “the most serious departure from economic efficiency.”

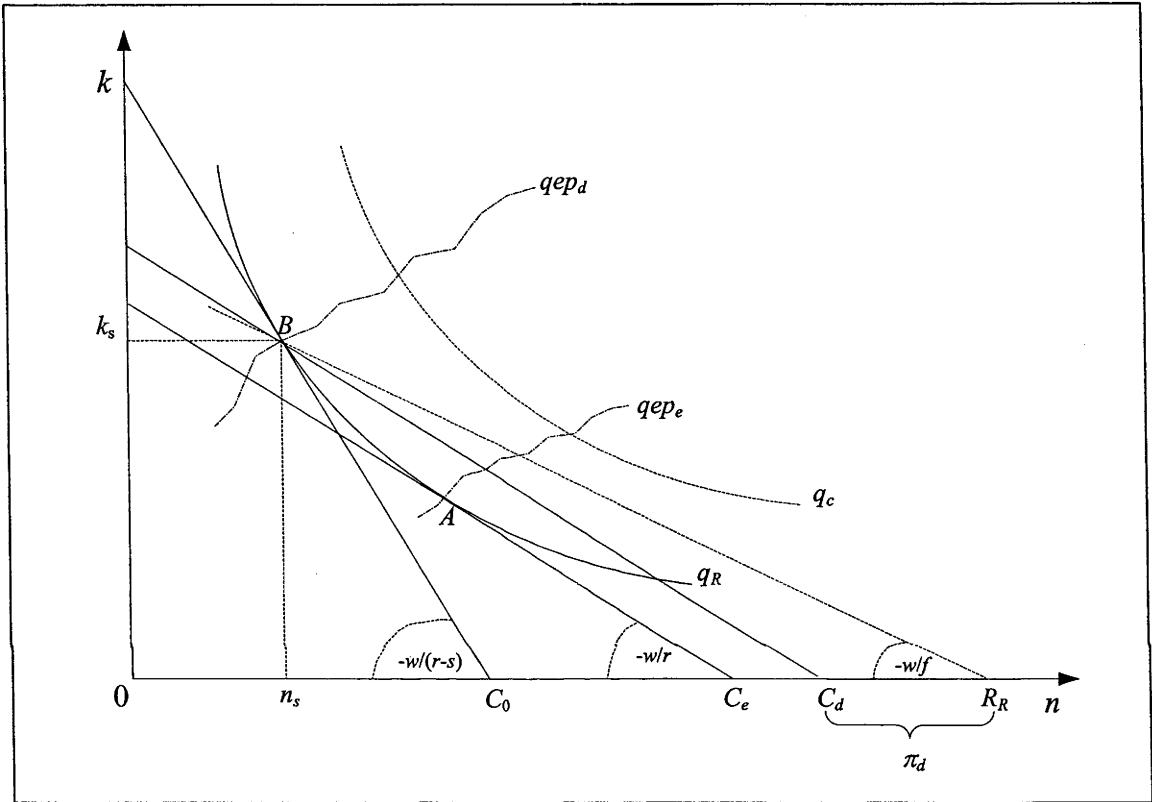
<sup>41</sup> Page 92-3.

<sup>42</sup> Westfield (1965) and Sheshinski (1971) both mention that output decreases if capital is an inferior factor of production, but do not appear to prove this result formally in their papers.

### 2.4.3 Depicting the AJ ROR-regulated Monopoly in the Input Space

The impact of ROR regulation on the monopoly under the AJ model is shown in the input-space diagram of Figure 2.4.1. This captures the cost of production to society and the firm from ROR regulation, the production inefficiency associated with the AJ effect, and the overall level of profit that is derived by the ROR-regulated monopoly.

**FIGURE 2.4.1 THE ROR-REGULATED MONOPOLY OUTCOME**



Rather than using the efficient cost-minimising input mix associated with point  $A$ , the ROR-regulated monopoly in Figure 2.4.1 produces output  $q_R$  using the inefficient input mix corresponding to point  $B$ . The result of this over-capitalisation, known as the AJ effect, is that there is a cost to the regulated monopoly and society of  $C_d$ , which exceeds the efficient cost of production  $C_e$ . The regulated monopoly now bears the cost of the production inefficiency associated with the AJ effect,  $C_d - C_e$ , because this inefficient input mix allows the firm to increase the total profits it earns at any given fair rate of return on capital  $f$ . This fair rate of return enables the firm to generate total revenue  $R_R$ , achieve a total return on capital  $R_R - C_0$ , and earn a regulated level of profit  $\pi_R$  equal to  $R_R - C_d$ .

## 2.5 Comparing the ROR-Regulated and Capital-Subsidised Monopoly

The similarity between a monopoly receiving an input subsidy on capital and a ROR-regulated monopoly has already been alluded to in Section 2.4. This Section further emphasises this previously unrecognised link that exists between the capital subsidy and fair rate of return. It does this by designing an “equivalent” capital subsidy, which ensures that the capital-subsidised and ROR-regulated monopoly employ the same input mix. From the equivalence result it is possible to show:

- (i) an identical outcome to ROR regulation in the AJ model can be achieved, by providing the monopoly with an equivalent capital subsidy, and then lump sum taxing an amount equal to the total capital subsidy payment made;
- (ii) that a monopoly subject to a lower fair rate employs an input mix consistent with it receiving a higher input subsidy on capital;
- (iii) that for a given level of production and zero marginal cost of funds, a production subsidy welfare-dominates ROR regulation. However, with a positive marginal cost of funds it is possible for ROR regulation to welfare-dominate a production subsidy;
- (iv) an identical outcome to price regulation can be achieved, by providing the monopoly with an equivalent production subsidy, and then lump sum taxing an amount equal to the total production subsidy payment made;
- (v) how Yang and Fox (1994) are able to achieve their results using a property tax (i.e. a capital tax) in the AJ model of ROR regulation;
- (vi) why a post-tax cost of capital — rather than a pre-tax cost of capital — combined with accelerated depreciation, has the potential to increase investment in capital; and
- (vii) why a regulator who over-estimates the capital costs of the firm, but sets the fair rate  $f$  as close as possible to  $r$ , may not maximise the social welfare under ROR regulation.

### 2.5.1 ROR Regulation and the Equivalent Capital Subsidy

Under ROR regulation and an input subsidy on capital, the monopoly uses an identical condition to determine the amount of labour it employs (i.e.  $MR.MP_n = w$ ), and some

lower user cost of capital than the market rate  $r$  to determine the amount of capital it employs. That is, the condition used by the ROR-regulated monopoly to employ capital is,

$$MR.MP_k = r - \mu^* (f - r) / (1 - \mu^*) = r', \text{ where } r > r' \quad (2.5.1)$$

and the condition used by the monopoly receiving an input subsidy on capital is,

$$MR.MP_k = r - s \quad (2.5.2)$$

Intuitively, the reason this similarity exists between the two regimes is that, the level of profit the regulated monopoly is allowed to earn is now directly linked to the amount of capital stock that it employs. As the fair rate of return  $f$  is set higher than the market rate of return  $r$ , the regulated monopoly, like the monopoly receiving capital subsidy, has the incentive to expand its capital base in order to increase the amount of net cash flow and profit it is allowed to earn. The result of this input distortion is a production inefficiency or deadweight loss.

Using equations (2.5.1) and (2.5.2), it is possible to design a scheme under which, the ROR-regulated monopoly, and the monopoly receiving an input subsidy on capital, employ the same level of capital and labour. By setting the capital subsidy in the following manner,

$$s = \mu^* (f - r) / (1 - \mu^*) \quad (2.5.3)$$

the ROR-regulated monopoly and the monopoly receiving the “equivalent” capital subsidy, now both use the following conditions to employ capital and labour.<sup>43</sup>

$$MR.MP_n = w \quad (2.5.4a)$$

$$MR.MP_k = r' \quad (2.5.4b)$$

This implies that there is a per-unit input subsidy  $s$  that corresponds to the given fair rate of return  $f$ . As equations (2.5.4a) and (2.5.4b) determine the levels of the two endogenous variables  $n$  and  $k$ , it follows that if  $r'$  is equal to  $r - s$ , an identical amount of

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<sup>43</sup> Kennedy (1977) suggests (at page 970) that one possible interpretation for the disparity in the ROR regulated firm's cost of capital and the true cost of capital is that, the firm observes “the wrong input prices in its input decision”. Based on the analysis here, a better interpretation for this behaviour might be that the ROR-regulated firm is under the mistaken belief that it is receiving a per-unit input subsidy on capital.

capital and labour is employed under the two schemes (i.e.  $n_R = n_s$ ,  $k_R = k_s$ ). This leads to,

- the same amount of output being produced (i.e.  $q_R = q_s$ );
- an identical price being charged (i.e.  $p_R = p_s$ );
- the same amount of total revenue (i.e.  $R_R = R_s$ );
- the same degree of inefficient over-capitalisation and production deadweight loss; and
- although not analysed here — provided there are no marginal costs associated with raising the funds to pay the capital subsidy — the same overall change in welfare.

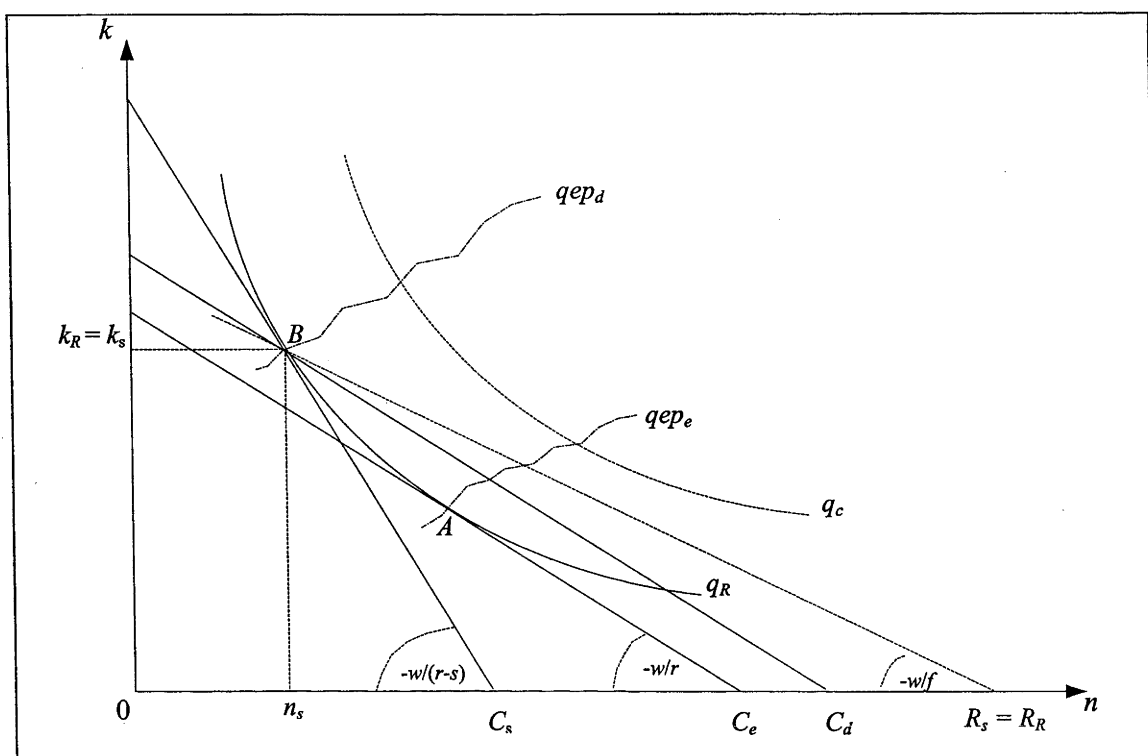
However, while all these outcomes are identical, it is important to recognise that the two schemes achieve very different distributional results.

The difference in the distributional outcomes between the ROR-regulated and capital-subsidised monopoly, arises due to the difference in the cost faced by each firm. While equation (2.5.4b) shows that both the capital-subsidised and ROR-regulated monopoly employ capital using the user cost of capital  $r'$ , only the capital-subsidised monopoly actually receives the benefit of the reduced user cost of capital. The ROR-regulated monopoly must still repay the market rate of interest  $r$  on the financial capital borrowed in the initial period. Consequently, it incurs a higher overall cost of production, and as both firms earn the same amount of total revenue, the ROR-regulated monopoly also earns a lower level of profit than the capital-subsidised monopoly. These results are highlighted in Figure 2.5.1.

Figure 2.5.1 shows that for the given input subsidy and fair rate of return, under each scheme, the monopoly produces along the inefficient output expansion path  $qep_d$  using the same distorted input mix at point  $B$  to produce output  $q_R$ . While this enables both firms to earn the same amount of revenue (i.e.  $R_R = R_s$ ), the over-capitalisation results in a production deadweight loss to society of  $C_d - C_e$ . With an input subsidy on capital, the cost of this production deadweight loss  $C_d - C_e$  is not borne by the producer. In fact, the over-capitalisation increases the size of the total subsidy payment made by the government, and overall the producer receives  $C_d - C_s$ . This decreases the firm's cost of production to  $C_s$  and results in the subsidised firm earning profit  $\pi_s$  of  $R_R - C_s$ . In contrast, the ROR-regulated monopoly absorbs the increased cost to society resulting from the production deadweight loss. Consequently, it incurs a cost of production of  $C_d$ , and only earns profit  $\pi_R$  equal to  $R_R - C_d$ .



FIGURE 2.5.1 ROR-REGULATION AND THE EQUIVALENT CAPITAL SUBSIDY



In theory, based upon these results, it is possible to develop a scheme using the input subsidy on capital that will yield exactly the same distributional outcomes as under ROR regulation. This will arise if the government can initially grant the monopoly the equivalent per-unit capital subsidy  $s$ , and then after the production plans of the firm have changed, levy an unanticipated lump-sum tax  $T$  on the producer that is exactly equal to the total amount of the subsidy payment made (i.e.  $T = s.k_s$ ). In Figure 2.5.1, the lump-sum tax  $T$  required to achieve the same distributional outcome must be equal to  $C_d - C_s$ .

While there are obvious reasons why this scheme could never be considered a viable alternative to ROR regulation in practice, it provides a useful pedagogical tool for introducing and understanding the AJ model of ROR regulation.

## 2.5.2 The Lower the Fair Rate, The Greater the Assistance to the Monopoly?

The question here is, given that an equivalent scheme is initially in place, when the input subsidy on capital increases, what change must happen to the fair rate of return so that an identical input choice and level of output is maintained? To answer this question it is first necessary to consider what happens when there is an increase in the capital subsidy.

When the input subsidy on capital granted to the monopoly increases, the level of profit, the degree of over-capitalisation, and the amount of output produced, all increase.<sup>44</sup> In assessing what should happen to the fair rate so that it has the same impact on capital and output, the first instinct might be to think that as the increased input subsidy on capital increases profit, an equivalent outcome is achieved by increasing  $f$ . It is clear though, that providing an infinitesimal capital subsidy will have very little impact upon the input choice and the overall level of output, and that this will be equivalent to setting a fair rate  $f$  that is only very slightly below the monopoly rate of return  $r_m$ . Therefore, intuitively, it follows that for a larger increase in the capital subsidy  $s$ , in order to induce the same level of over-capitalisation and output, there must be a greater decrease in the fair rate of return  $f$  set by the regulator. Takayama (1969) and Baumol and Klevorick (1970) formally highlight this relationship between capital and the fair rate, by deriving the expression,<sup>45</sup>

$$\frac{dk}{df} = \frac{k}{(MRMP_k - f)} \quad (2.5.5)$$

As  $k > 0$  and  $f > r > MRMP_k$ , the expression in equation (2.5.5) for  $dk/df$  must be less than zero. This means that a decrease in the fair rate of return always leads to an increase in the level of inefficient over-capitalisation in production.

Therefore, in order to maintain the same input choice under each regime, an increase in the input subsidy on capital, must be met with a corresponding decrease in the fair rate of return. Alternatively, decreasing the fair rate for ROR-regulated monopoly is equivalent to increasing the rate of the per-unit capital subsidy. This result appears somewhat paradoxical. It implies that, the more restrictive the profit constraint imposed by the regulator, the higher the implicit per-unit subsidy on capital that is reflected in the input choice by the regulated firm. The result is highlighted in Figure 2.5.2.

Figure 2.5.2 shows that without ROR regulation or an input subsidy on capital, the monopoly uses the efficient input mix at point  $M$  and produces  $q_m$  units of output. When the monopoly faces the regulated fair rate of return  $f_0$  or receives the equivalent input subsidy on capital  $s_0$ , the firm produces  $q_{R0}$  units of output using the inefficient

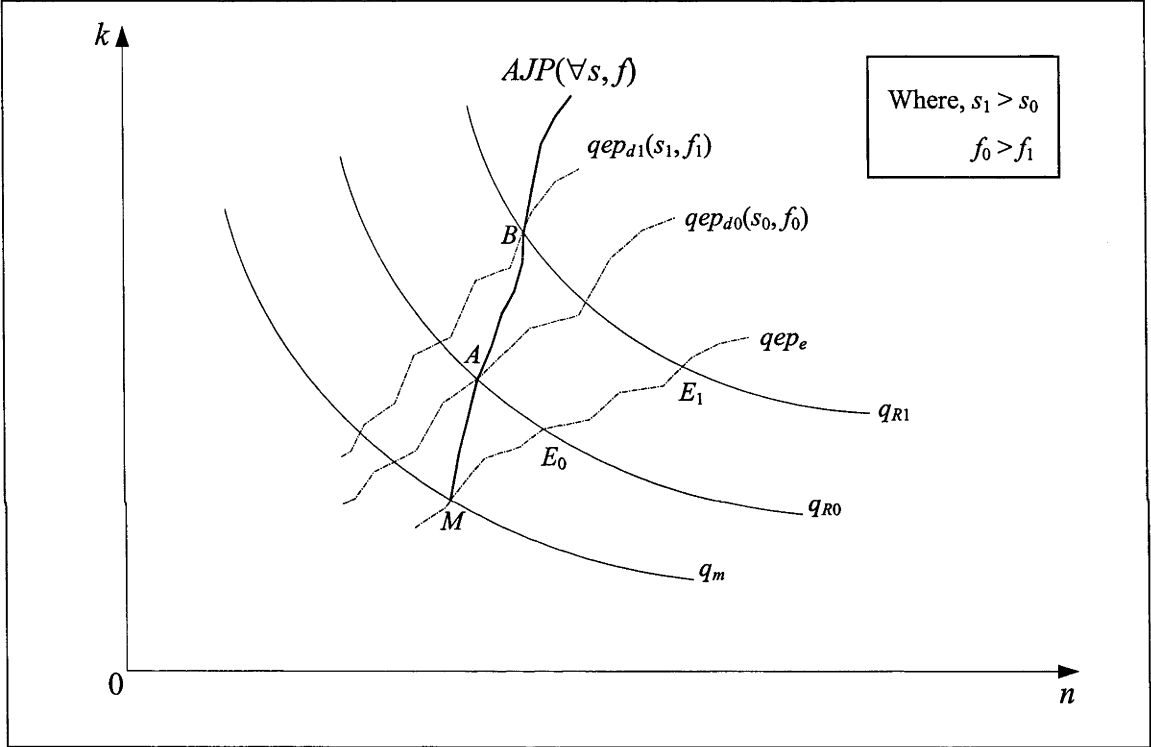
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<sup>44</sup> The increase in output and profit occurs because of the assumption made that capital is a normal factor of production.

<sup>45</sup> Westfield (1965) and Zajac (1970) both use diagrams to show that a decrease in the fair rate  $f$  will lead to an increase in the overall level of capital employed by the firm.

input mix associated with point  $A$ . This capital and labour choice by the firm lies along the distorted output expansion path  $qep_{d0}(f_0, s_0)$ . For a lower fair rate of return  $f_1$  or a higher equivalent input subsidy on capital  $s_1$ , the monopoly will increase the level of production to  $q_{R1}$  units of output. However, the input mix at point  $B$  used to produce this higher level of output  $q_{R1}$ , involves an even greater input distortion by the firm. This is evident in Figure 2.5.2 by the fact that the output expansion path associated with  $f_1$  and  $s_1$  —  $qep_{d1}(f_1, s_1)$  — diverges even further away from the efficient output expansion path  $qep_e$ .

**FIGURE 2.5.2 DECREASING THE FAIR RATE AND INCREASING THE CAPITAL SUBSIDY**



Instead of drawing a separate output expansion path for each given fair rate of return, Baumol and Klevorick, and Bailey, use a diagram where one path maps all the distorted input mixes that are used by the firm for each given fair rate of return  $f$ . Bailey refers to this locus of points as the Averch-Johnson Path, and in Figure 2.5.2, this path is depicted by the line denoted  $AJP$ . This starts at point  $M$  and passes through both points  $A$  and  $B$ .

### 2.5.3 Does a Production Subsidy Welfare-Dominate ROR Regulation?

It has been established that subsidising production will normally be a more efficient way of stimulating an increase in output than subsidising only one factor of production such as capital.<sup>46</sup> For the same increase in output, a capital subsidy creates an additional inefficiency, as it distorts the input choice of the firm. Consequently, if a production subsidy granted to the monopoly achieves the same level of output  $q_s$  as a capital subsidy, it must lead to a higher level of welfare. Using the equivalence result, and ignoring the marginal cost associated with using distortionary taxes to raise the funds required to pay the subsidy — i.e. assuming a marginal excess burden of zero — it also follows that for a given level of output, i.e.  $q_R = q_s$ , the production subsidy leads to a higher level of welfare than ROR regulation. Using Figure 2.5.1, it is possible to illustrate this welfare-superiority of the production subsidy.

In Figure 2.5.1, the production subsidy leads to the monopoly producing output  $q_R$  using the capital-labour input mix at point  $A$ , which lies along the efficient output expansion  $qep_e$ . From this it is evident that compared to the capital-subsidised and ROR-regulated monopoly, the production subsidy leads to less capital and more labour being employed, and with a marginal excess burden of zero, the result is a lower overall cost of production to society  $C_e$ .

Where there is a positive marginal cost associated with using distortionary taxes to raise funds required for the subsidy payment — i.e. a positive marginal excess burden — it is possible that a production subsidy will no longer lead to a higher level of welfare than ROR regulation, when the same level of output is produced. For this to occur, the marginal excess burden associated with using distortionary taxes to fund the production subsidy, must be greater than the production deadweight loss that results from ROR regulation. Where the marginal excess burden is denoted by  $\omega$ , and the total subsidy payment required for the firm to produce  $q_R$  is  $S$ , the distortionary impact of raising funds is equal to  $\omega.S$ . If ROR regulation results in a production deadweight loss that is equal to some amount  $X$ , then the condition that must be satisfied for ROR regulation to welfare-dominate the production subsidy is  $\omega S > X$ , or alternatively  $\omega > X/S$ . That is, the marginal excess burden must exceed an amount that is equal to: the production deadweight loss from ROR regulation, divided by the total production subsidy payment

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<sup>46</sup> This result is implicit in the analysis that has been done by Carlton (1979) and was made explicit in the work of Albon (1998).

that is required to produce the same level of output as under ROR regulation. As in Figure 2.5.1, the production deadweight loss is  $C_d - C_e$  and the total subsidy payment is  $C_e - C_s$ , the level the positive marginal cost of funds must exceed for society to be better off under ROR regulation, can also be expressed as,

$$\omega > \frac{C_d - C_e}{C_e - C_s} \quad (2.5.6)$$

Based upon estimates of the marginal excess burden in Australia by Campbell and Bond (1997), for a production subsidy to yield a lower level of welfare than ROR regulation, the value of the left-hand side of the condition in equation (2.5.6), will need to be less than 0.24.

#### 2.5.4 Price Regulation and the Equivalent Production Subsidy

As ROR regulation is equivalent to granting the monopoly a capital subsidy and lump sum taxing an amount equal to total capital subsidy paid, it follows that; price regulation is equivalent to, providing the monopoly with a production subsidy and lump sum taxing an amount equal to the total production subsidy paid.<sup>47</sup> In Figure 2.5.1, the equivalent regime to price regulation, involves a production subsidy payment of  $C_e - C_s$ , and then after the production plans of the monopoly have changed, an unanticipated lump-sum tax equal to this amount.

As the equivalent production subsidy combined with a lump-sum tax is identical to the outcome where there is a production subsidy with no marginal excess burden, it also follows that price regulation leads to a higher level of welfare than ROR regulation. As opposed to ROR regulation, under price regulation there is no inefficient over-capitalisation or distortion in the input mix used by the monopoly. The result provides an insight into why a form of price regulation, known as “price-cap regulation”, is now preferred by regulatory authorities to traditional US-style ROR regulation.

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<sup>47</sup> Stephen King also raised this point when discussing a paper I presented at the 2002 PhD Conference at the ANU, which this Section is based on.

### 2.5.5 The Property Tax of Yang and Fox (1994)

Yang and Fox (1994) incorporate a property tax (i.e. a tax on the capital assets of the firm) into the AJ model of ROR regulation.<sup>48</sup> By then solving for the FOCs, they formally show that:

- changing the tax on capital has exactly the same impact on the firm's capital, labour, price, output and profits, as changing the regulated fair rate;<sup>49</sup> and
- increasing the level of the capital tax can potentially increase welfare.

The intuition for why they are able to achieve both these results with the introduction of a capital tax becomes immediately obvious, once the equivalence result established in Section 2.5.1 is recognised.

Given that a ROR-regulated monopoly behaves as if it is receiving a capital subsidy, and that a lower fair rate translates into a higher implicit subsidy on capital, it follows that the introduction of a capital tax is equivalent to increasing the allowed fair rate of return. Therefore, in terms of the input choice, the capital tax has the effect of partially offsetting the original over-capitalisation and production inefficiency generated by ROR regulation. This can potentially lead to an overall increase in welfare if the benefits from the decrease in the production inefficiency, exceed the allocative efficiency losses from the decrease in the supply of output being produced. As welfare under ROR regulation is examined in Chapter 3, the situations where a capital tax increases welfare are addressed and illustrated in greater detail there.

### 2.5.6 Comparing the Pre-Tax and Post-Tax Cost of Capital

In Australia, the regulator generally determines the fair rate of return firms are allowed to earn across a number of regulated industries, by calculating a weighted average cost-of-capital, or what is commonly known as the "WACC". The equivalence result established here can be used to assess whether a pre-tax or post-tax WACC, combined with accelerated depreciation, will encourage greater investment. Currently, this issue is relevant in Australia, in the regulation of gas pipelines.

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<sup>48</sup> Bailey (1973) page 99–101 originally discussed invariance properties of a property tax, but did not formalise any of the results.

<sup>49</sup> Although this outcome suggests YF understand that a ROR-regulated monopoly behaves as if it is receiving a capital subsidy, a detailed assessment of their paper — done in Chapter 3, Section 3.6 — indicates that they did not appreciate the equivalence result outlined here.

After the Government recently decided to remove accelerated depreciation provisions across industries, objections from representatives of the gas industry, led to the provision being reinstated for gas pipelines. As accelerated depreciation is a form of capital subsidy, the Government may have been motivated to retain the provision, in an attempt to stimulate investment in pipelines. However, because the regulator calculates a post-tax WACC, this has led to bigger depreciation deductions, and pipeline owners ultimately receiving a lower regulated rate of return than they would otherwise have derived from accelerated depreciation. Consequently, industry participants have argued in favour of a pre-tax WACC, which allows the firm to keep the benefits of accelerated depreciation and effectively earn a higher regulated rate of return.

The equivalence result is of interest here, as it implies that a post-tax WACC, by lowering the rate of return, may lead to higher levels of investment than a pre-tax WACC, despite being less attractive to investors.<sup>50</sup> Of course though, it must be recognised that this outcome relies on the regulator not setting the rate of return so low, that it causes investment to cease altogether.

#### 2.5.7 The Better the Regulator, The Worse the Outcome?

Where there is little or no competition in an industry, regulators are often under a statutory duty to establish a framework that will simulate the effects of a competitive market. If reproducing the competitive market effects is interpreted by the regulator as setting a fair rate of return  $f$  as close as possible to  $r$ , then the outcome in the AJ model indicates that it is possible for a regulator that is better in fulfilling this duty, to create a worse outcome for society.

In practice, a regulator will encounter problems in setting the fair rate equal to  $r$ . There has been significant disagreement over how the appropriate fair rate should be calculated. In recent years in Australia, the cost of capital calculation has been complicated by the need to account for dividend imputation.<sup>51</sup> A consequence of this may be that a regulator, endeavouring to set the regulated fair rate equal to  $r$ , could set  $f$

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<sup>50</sup> The merits of whether increased capital investment is socially beneficial is not specifically addressed in this sub-section.

<sup>51</sup> Although it is accepted that offsetting imputation credits against tax paid by shareholders lowers the cost of equity to the firm, Hathaway (1998) observes there is yet to be any agreement as to how to account for taxation and dividend imputation in the weighted average cost of capital (WACC) calculation. For conflicting approaches see Officer (1994), Monkhouse (1993) and Brailsford and Davis (1995).

either below or in excess of  $r$ . As consistently setting the fair rate below  $r$  leads to the regulated monopoly becoming insolvent and no service being provided, the regulator is more likely to set the fair rate conservatively, so that  $f$  is set slightly in excess of  $r$  (i.e.  $f = r + \varepsilon$ , where  $\varepsilon > 0$ ). The AJ model suggests that if the regulator is likely to over-estimate the fair rate, then it may not be optimal for the regulator to attempt to set  $f$  as close as possible to  $r$ .

Although setting  $f$  closer to  $r$  further constrains profits and provided capital is a normal input, increases the quantity supplied, it also increases the level of inefficient over-capitalisation, as the firm behaves as if it is receiving a higher input subsidy on capital. Although the impact of ROR regulation on welfare in the AJ model is not explicitly dealt with until the next Chapter, the results here suggest that as the fair rate  $f$  is decreased towards  $r$ , there is the potential for the marginal production inefficiency to outweigh any increase in the marginal net benefits from the additional units of output supplied. Such an outcome would decrease welfare, and the policy implication is that it is possible for a “better” regulator — one who sets the fair rate of return as close as possible to  $r$  — to reduce the gains to society achievable through ROR regulation.<sup>52</sup> The prevailing market conditions when it is optimal for the regulator to set  $f$  in excess of  $r$ , are explored in the welfare analysis of Chapter 3.

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<sup>52</sup> Sheshinski (1971) illustrates the potential for an outcome where the welfare-maximising fair rate exceeds  $r$ .



## 2.6 An Alternative Model of ROR Regulation

The previous Section illustrated that an identical outcome to ROR regulation in the AJ Model is achieved if the Government provides an equivalent capital subsidy, and then levies a lump-sum tax equal to the amount of the total subsidy payment made. Here it is shown that an equivalent subsidy can be found, by establishing an alternative model where shareholders instruct the management of the ROR-regulated monopoly, to behave as if the firm is receiving a capital subsidy. In the framework adopted in this Section, there are three agents:

- (i) a regulator who sets the fair rate  $f$  such that,  $r_m > f \geq r$ ;
- (ii) perfectly-informed-total-dividend-maximising shareholders; and
- (iii) a manager who acts on the instructions of shareholders.

The set up here leads to exactly the same pattern of inefficient over-capitalisation as in the AJ model. While the assumptions are obviously unrealistic, as it implicitly relies on shareholders being better informed about the performance of the firm than managers, the advantage of using the model is that it derives an expression for the capital subsidy as a function of the fair rate set by the regulator. By doing this, it is possible to translate any given fair rate  $f$  into an equivalent capital subsidy  $s$ . This is illustrated diagrammatically using a simple numerical example, and confirms the outcome that, setting a lower fair rate is equivalent to providing a higher capital subsidy.

### 2.6.1 A Model of ROR Regulation with Shareholders and Management

#### 2.6.1.1 Assumptions of The Model

In this model, the following modifications are made to the earlier assumptions outlined in Section 2.2 and 2.4:

- the regulator sets the fair rate  $f$  such that,  $r_m > f \geq r$ ,<sup>53</sup>
- the only source of financial capital for the firm is equity capital;

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<sup>53</sup> Unlike the AJ model it is assumed here that when  $f$  is set equal to  $r$ , there is a unique solution where the firm still inefficiently over-capitalises in production.

- there are no capital gains here and shareholders receive all profits of the firm as dividends. Shareholders aim to maximise the total dividend payments they receive  $D$ , where  $D = r.k + \pi$ ,
- shareholders are perfectly-informed about the impact ROR regulation has on their total dividend payments; and
- management acts on the instructions of the shareholders.<sup>54</sup>

In this model of ROR regulation, shareholders realise the allowed fair rate restricts the total dividend payments they are able to achieve. Therefore, in order to maximise their total dividend payments, they instruct the manager to behave as if it is maximising the unregulated profits of a capital-subsidised monopoly.

#### 2.6.1.2 The Behaviour of Management

As the shareholders of the ROR-regulated monopoly instruct the manager to behave as if it is receiving the per-unit capital subsidy  $s$ , the manager uses a production plan based on the discounted user cost of capital  $r - s > 0$ , and chooses capital and labour to,

$$\max_{n,k} \pi = pq - wn - (r - s)k \quad (2.6.1)$$

Using the analysis from Section 2.4, the FOCs can be simplified and solved here for

$$MRMP_n = w \quad (2.6.2a)$$

$$MRMP_k = r - s \quad (2.6.2b)$$

Equation (2.6.2a) and (2.6.2b) can then be rearranged and expressed in terms of the marginal revenue.

$$MR = w/MP_n = (r - s)/MP_k \quad (2.6.3)$$

The management of the firm continues producing until the marginal revenue is equal to the subsidised private marginal cost of production it observes. Denoting this private marginal cost of production by subscript  $s$ , it will be equal to,

$$MC_s = w/MP_n = (r - s)/MP_k \quad (2.6.4)$$

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<sup>54</sup> Implicitly this relies on the manager being almost unaware or even ignorant of the effects of ROR regulation.

As in the AJ model, in this model of ROR regulation with shareholders and management, the FOCs indicate that there is inefficient over-capitalisation in the production of output by the firm. That is, rearranging equation (2.6.3),

$$\frac{MP_n}{MP_k} = \frac{w}{r-s} > \frac{w}{r} \quad (2.6.5)$$

Now, if an explicit functional form is given for the production technology used by management of the firm and the inverse demand curve for the industry  $p(q)$ , equations (2.6.2a) and (2.6.2b) can be solved for the following optimal outcomes,

$$k_R = k_R(w, r-s) \quad (2.6.6a)$$

$$n_R = n_R(w, r-s) \quad (2.6.6b)$$

$$q_R = h(n_R, k_R) = q_R(w, r-s) \quad (2.6.6c)$$

$$p_R = p(h(n_R, k_R)) = p_R(w, r-s) \quad (2.6.6d)$$

The profit observed if the monopoly were subsidised is,

$$\pi_s = \pi(n_R, k_R) = \pi_s(w, r-s) \quad (2.6.6e)$$

However, as the ROR-regulated monopoly does not actually receive the capital subsidy, and just behaves in this manner on the instruction of shareholders, the actual level of profits is,

$$\pi_R = \pi_s(w, r-s) - sk_R(w, r-s) = \pi_R(n_R, k_R) \quad (2.6.6f)$$

This can then be used to solve to give the total dividend payments shareholders receive,

$$D_R = D(n_R, k_R) = D_R(w, r-s) \quad (2.6.6g)$$

### 2.6.1.3 The Behaviour of Shareholders

The issue addressed here is, how the shareholder should set the capital subsidy  $s$ , so that the manager maximises the total dividend payments shareholders receive at any given fair rate of return set by the regulator  $f$ . The total dividend payment to shareholders can be stated here as being equal to the fair rate of return times the number of units of capital employed; or the profit of the capital-subsidised monopoly, plus the total return on equity capital, minus the cost of the capital subsidy. That is,

$$D_R = fk_R = \pi_s + rk_R - sk_R \quad (2.6.7)$$

Rearranging the above expression to ensure that the input subsidy on capital  $s$  is the subject of the equation yields,

$$s = \frac{\pi_s}{k_R} + r - f \quad (2.6.8)$$

Substituting equations (2.6.6a) and (2.6.6e) into the above expression in (2.6.8), the capital subsidy  $s$  that shareholders instruct the manager to employ in the production schedule for any given regulated fair rate  $f$ , can be solved to give,

$$s = s(w, r, f) \quad (2.6.9)$$

By substituting the expression for the capital subsidy into equations (2.6.6a) through to (2.6.6g), each of the identities can be re-expressed as a function of the given fair rate  $f$ . That is,

$$k_R = k_R(w, r, f) \quad (2.6.10a)$$

$$n_R = n_R(w, r, f) \quad (2.6.10b)$$

$$q_R = h(n_R, k_R) = q_R(w, r, f) \quad (2.6.10c)$$

$$p_R = p(h(n_R, k_R)) = p_R(w, r, f) \quad (2.6.10d)$$

$$\pi_s = \pi(n_R, k_R) = \pi_s(w, r, f) \quad (2.6.10e)$$

$$\pi_R = \pi_s - s k_R = \pi_R(w, r, f) \quad (2.6.10f)$$

$$D_R = D(n_R, k_R) = D_R(w, r, f) \quad (2.6.10g)$$

## 2.6.2 ROR Regulation with Shareholders and Management: A Worked Example

Assuming an explicit functional form for production technology and the industry demand curve, a worked example is provided here that derives the outcomes described in the previous Section. In particular, an expression is found that gives the per-unit capital subsidy  $s$  as a function of the fair rate of return on capital  $f$  (i.e.  $s(f)$ ).

The firm is assumed to be subject to the Cobb-Douglas production technology of,

$$q = h(n, k) = n^{\frac{1}{2}} k^{\frac{1}{2}} \quad (2.6.11)$$

and face a linear industry inverse demand curve of,

$$p(h(n, k)) = a - bq, \text{ where } a, b > 0 \quad (2.6.12)$$

Based on the assumptions about production technology and industry demand, the equilibrium price is equal here to,

$$p = a - bn^{\frac{1}{2}} k^{\frac{1}{2}} \quad (2.6.13)$$

### 2.6.2.1 The Unregulated Monopoly Outcome

Therefore, an unregulated monopoly will,

$$\max_{n,k} \pi = (a - bn^{\frac{1}{2}}k^{\frac{1}{2}})n^{\frac{1}{2}}k^{\frac{1}{2}} - wn - rk$$

This yields the FOCs

$$\frac{\partial \pi}{\partial n} = (a - 2bn^{\frac{1}{2}}k^{\frac{1}{2}})\frac{1}{2}\left(\frac{k}{n}\right)^{\frac{1}{2}} - w = 0 \quad (2.6.14a)$$

$$\frac{\partial \pi}{\partial k} = (a - 2bn^{\frac{1}{2}}k^{\frac{1}{2}})\frac{1}{2}\left(\frac{n}{k}\right)^{\frac{1}{2}} - r = 0 \quad (2.6.14b)$$

Using subscript  $e$  to denote the production efficient outcome, the FOCs are solved to give,

$$MR = (a - 2bn^{\frac{1}{2}}k^{\frac{1}{2}}) = MC_e = 2w\left(\frac{n}{k}\right)^{\frac{1}{2}} = 2r\left(\frac{k}{n}\right)^{\frac{1}{2}} \quad (2.6.15)^{55}$$

This can be used to solve for the amount of labour and capital employed by the monopoly,

$$n_m = n_m(w, r) = \frac{1}{b}\left(\frac{r}{w}\right)^{\frac{1}{2}}\left(\frac{a}{2} - w^{\frac{1}{2}}r^{\frac{1}{2}}\right) \quad (2.6.16a)$$

$$k_m = k_m(w, r) = \frac{1}{b}\left(\frac{w}{r}\right)^{\frac{1}{2}}\left(\frac{a}{2} - w^{\frac{1}{2}}r^{\frac{1}{2}}\right) \quad (2.6.16b)$$

Substituting these values into equation (2.6.11) yields the level of output supplied by the unregulated monopoly,

$$q_m = q_m(w, r) = \frac{1}{b}\left(\frac{a}{2} - w^{\frac{1}{2}}r^{\frac{1}{2}}\right) \quad (2.6.16c)$$

Substituting  $q_m$  into equation (2.6.12), the unregulated monopoly price is,

$$p_m = p_m(w, r) = \frac{a}{2} + w^{\frac{1}{2}}r^{\frac{1}{2}} \quad (2.6.16d)$$

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<sup>55</sup> As there is constant-returns-to-scale technology, this implies that in the absence of any shared or common costs of production, the expression for the long-run marginal cost here is also the expression for the long-run average cost.

Multiplying equation (2.6.16c) by (2.6.16d), leads to the unregulated monopoly earning total revenue of,

$$R_m = \frac{1}{b} \left[ \left( \frac{a}{2} \right)^2 - \left( w^{\frac{1}{2}} r^{\frac{1}{2}} \right)^2 \right]$$

and substituting in the expressions for  $n_m$  and  $k_m$ , the total cost of production is

$$C_m = wn_m + rk_m = \frac{2w^{\frac{1}{2}}r^{\frac{1}{2}}}{b} \left( \frac{a}{2} - w^{\frac{1}{2}}r^{\frac{1}{2}} \right)$$

Thus, the unregulated monopoly earns total profit of

$$\pi_m = \pi_m(w, r) = \frac{1}{b} \left( \frac{a}{2} - w^{\frac{1}{2}}r^{\frac{1}{2}} \right)^2 \quad (2.6.16e)$$

The rate of return on the capital invested by shareholders in the unregulated monopoly is then equal to,

$$r_m = \frac{\pi_m}{k_m} + r = r_m(w, r) = \frac{a}{2} \left( \frac{r}{w} \right)^{\frac{1}{2}} \quad (2.6.16f)$$

and the total dividend payment made to shareholders is

$$D_m = r_m k_m = \pi_m + rk_m = D_m(w, r) = \frac{a}{2b} \left( \frac{a}{2} - w^{\frac{1}{2}}r^{\frac{1}{2}} \right) \quad (2.6.16g)$$

Further, using equation (2.6.15) and equations (2.6.16a) and (2.6.16b), the efficient marginal and average cost of production faced by the unregulated monopoly and society will be

$$MC_e(w, r) = AC_e(w, r) = 2w^{\frac{1}{2}}r^{\frac{1}{2}} \quad (2.6.16h)$$

Examining these solutions, it is apparent that the restriction that must be placed on the parameters to ensure that  $k_m, n_m, q_m, D_m > 0$ , and  $r_m > r$  is,

$$a^2 > 4wr$$

#### 2.6.2.2 The Behaviour of Management

A the manager of the ROR-regulated monopoly is instructed by shareholders to behave as if the monopoly receives a given capital subsidy  $s$ , it responds by,

$$\max_{n, k} \pi = \left( a - bn^{\frac{1}{2}}k^{\frac{1}{2}} \right) n^{\frac{1}{2}}k^{\frac{1}{2}} - wn - (r - s)k, \text{ where } r > s$$

As the problem is exactly the same as that faced by an unregulated monopoly, except there is now a lower cost of capital  $r - s$ , it follows that the FOCs here can be solved to yield an expression for the private marginal cost of production that the manager bases its decision upon.

$$MR = \left(a - 2bn^{\frac{1}{2}}k^{\frac{1}{2}}\right) = MC_s = 2w\left(\frac{n}{k}\right)^{\frac{1}{2}} = 2(r-s)\left(\frac{k}{n}\right)^{\frac{1}{2}} \quad (2.6.17)$$

Using this condition, the following expressions are derived for the amount of labour  $n_R$  and capital  $k_R$  employed by the ROR-regulated monopoly,

$$n_R = n_R(w, r-s) = \frac{1}{b}\left(\frac{r-s}{w}\right)^{\frac{1}{2}}\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}}\right) \quad (2.6.18a)$$

$$k_R = k_R(w, r-s) = \frac{1}{b}\left(\frac{w}{r-s}\right)^{\frac{1}{2}}\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}}\right) \quad (2.6.18b)$$

Using the above expressions the following solutions are derived,

$$q_R = q_R(w, r-s) = \frac{1}{b}\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}}\right) \quad (2.6.18c)$$

$$p_R = p_R(w, r-s) = \frac{a}{2} + w^{\frac{1}{2}}(r-s)^{\frac{1}{2}} \quad (2.6.18d)$$

$$\pi_s = \pi_s(w, r-s) = \frac{1}{b}\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}}\right)^2 \quad (2.6.18e)$$

As the monopoly does not actually receive the benefit of the capital subsidy (i.e.  $sk$ ), for any given per-unit capital subsidy, the level of profit the firm earns, or that is received by shareholders, is equal to  $\pi_R$ , where

$$\pi_R = \pi_R(w, r-s) = \frac{1}{b}\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}}\right)\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}} - s\left(\frac{w}{r-s}\right)^{\frac{1}{2}}\right) \quad (2.6.18f)$$

Hence, the total dividend payment to shareholders is

$$D_R = D_R(w, r-s) = \frac{a}{2b}\left(\frac{a}{2} - w^{\frac{1}{2}}(r-s)^{\frac{1}{2}}\right) \quad (2.6.18g)$$

Substituting the expressions for  $n_R$  and  $k_R$  into equation (2.6.17), the private marginal cost of production used by the manager is,

$$MC_s = MC_s(w, r-s) = 2w^{\frac{1}{2}}(r-s)^{\frac{1}{2}} \quad (2.6.18h)$$

As  $s$  is strictly greater than zero, the restriction  $a^2 > 4wr$  ensures that there are positive amounts for capital, labour, output and dividend payments.

### 2.6.2.3 The Maximisation Problem for Shareholders

To find the capital subsidy the shareholder instructs management to use in its production plan in response to any given regulated fair rate of return, equations (2.6.18b) and (2.6.18e) are substituted into equation (2.6.8) to give,

$$s = s(w, r, f) = r - \frac{4f^2 w}{a^2} \quad (2.6.19)$$

If this equation is correct, when the fair rate  $f$  is set equal to the monopoly rate of return  $r_m$ , the capital subsidy provided by shareholders  $s$  should be equal to zero. To see that this holds, the expression for  $r_m$  in equation (2.6.16f) is substituted in for  $f$  in equation (2.6.19), which yields,

$$s = s(w, r, f) = r - \frac{4\left(\frac{a}{2}\left(\frac{r}{w}\right)^{\frac{1}{2}}\right)^2 w}{a^2} = r - \frac{4a^2 wr}{4a^2 w} = 0$$

Substituting equation (2.6.19) into the expression previously derived for capital, labour, output, price, profit and total dividend payments, equations (2.6.18a) through to (2.6.18f), can be expressed as a function of the given fair rate of return  $f$ . That is,

$$n_R = n_R(w, r, f) = \frac{1}{b} \left( \frac{2f}{a} \right) \left( \frac{a}{2} - \frac{2wf}{a} \right) \quad (2.6.20a)$$

$$k_R = k_R(w, r, f) = \frac{1}{b} \left( \frac{a}{2f} \right) \left( \frac{a}{2} - \frac{2wf}{a} \right) \quad (2.6.20b)$$

$$q_R = q_R(w, r, f) = \frac{1}{b} \left( \frac{a}{2} - \frac{2wf}{a} \right) \quad (2.6.20c)$$

$$p_R = p_R(w, r, f) = \frac{a}{2} + \frac{2wf}{a} \quad (2.6.20d)$$

$$\pi_s = \pi_s(w, r, f) = \frac{1}{b} \left( \frac{a}{2} - \frac{2wf}{a} \right)^2 \quad (2.6.20e)$$

$$\pi_R = \pi_R(w, r, f) = \frac{a}{2b} \left( \frac{a}{2} - \frac{2wf}{a} \right) \left( 1 - \frac{r}{f} \right) \quad (2.6.20f)$$

$$D_R = D_R(w, r, f) = \frac{a}{2b} \left( \frac{a}{2} - \frac{2wf}{a} \right) \quad (2.6.20g)$$



$$MC_s = MC_s(w, r, f) = \frac{4wf}{a} \quad (2.6.20h)$$

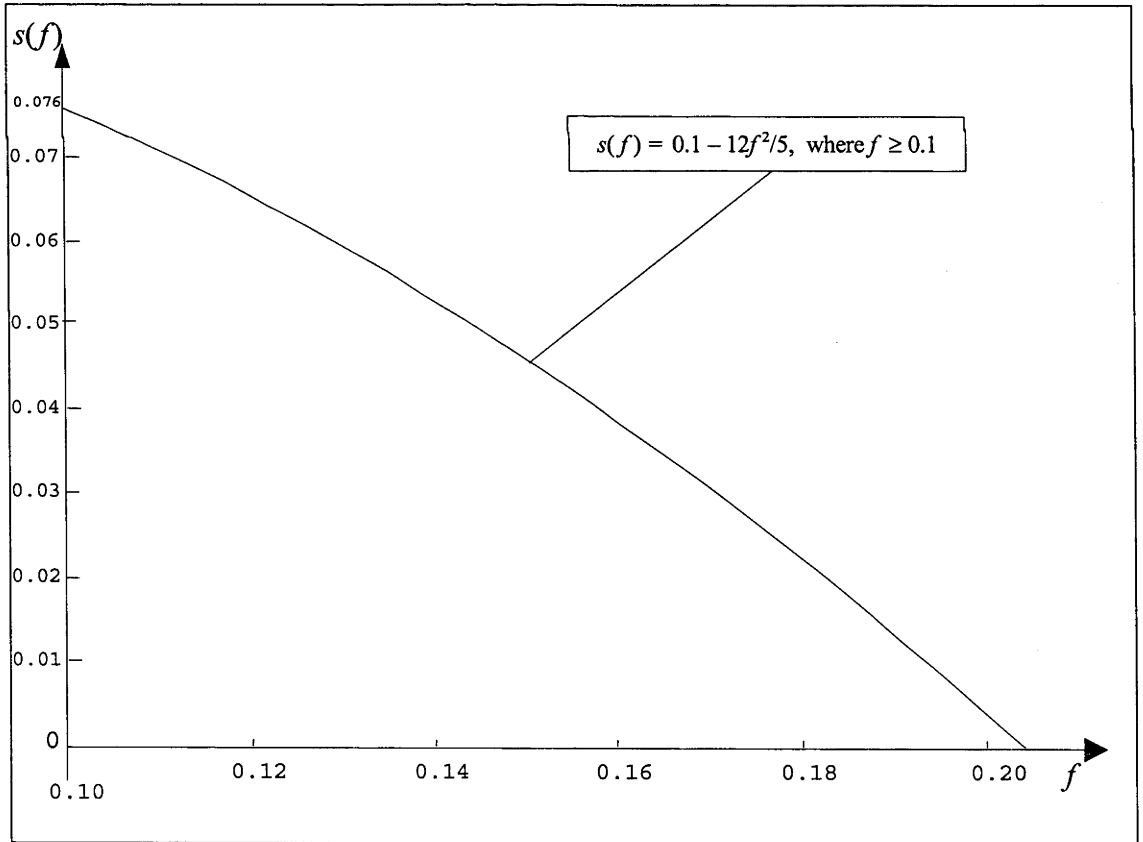
The importance of equation (2.6.19) is that it translates any given fair of return  $f$  into an equivalent input subsidy on capital  $s$ . By taking the first and second derivatives of equation (2.6.19), it is illustrated that the equivalent capital subsidy  $s$  is decreasing and concave in the regulated fair rate  $f$ . That is,

$$\begin{aligned} \frac{ds}{df} &= -\frac{8fw}{a^2} < 0 \\ \frac{d^2s}{df^2} &= -\frac{8w}{a^2} < 0 \end{aligned} \quad (2.6.21)$$

To highlight this outcome, the parameter values are set so:  $a = 5$ ,  $r = 0.1$  and  $w = 15$ . This implies that the expression in equation (2.6.20) will be equal to,

$$s(f) = 0.1 - \frac{12f^2}{5} \quad (2.6.22)$$

**FIGURE 2.6.1 THE CAPITAL SUBSIDY AS A FUNCTION OF THE FAIR RATE**



The values for the outcome illustrated in Figure 2.6.1 are outlined in Table 2.6.1.

**TABLE 2.6.1 THE FAIR RATE AND EQUIVALENT CAPITAL SUBSIDY**

$r$	$s(r)$
$r = 0.10$	0.076
0.12	0.065
0.14	0.053
0.16	0.039
0.18	0.022
0.20	0.004
$r_m = 0.2041$	0

This alternative model of ROR regulation and the numerical example provided here, are explored again during the course of Chapter 3, which examines welfare under ROR regulation.

## 2.7 Conclusion

This Chapter highlights the similarity between the behaviour of a monopoly subject to ROR regulation in the AJ model and a monopoly receiving a capital subsidy. By recognising the equivalence between the two schemes it is possible to illustrate a number of theoretical and potential policy implications. For example, it has been shown here that:

- an identical outcome to ROR regulation in the AJ model can be achieved by simply combining the equivalent capital subsidy with a lump-sum tax equal to the total subsidy payment that was made;
- there is the paradoxical result, that when the ROR-regulated monopoly is subject to a lower fair rate, it employs an input mix consistent with the capital-subsidised monopoly receiving a higher per-unit capital subsidy;
- for a given level of production and where the marginal excess burden is zero, a production subsidy welfare-dominates ROR regulation. However, with a positive marginal excess burden, it is possible for ROR regulation to induce a higher level of welfare;
- an identical outcome to price regulation is achieved by combining an equivalent production subsidy with a lump-sum tax equal to the total amount of the production subsidy payment;
- the results achieved by Yang and Fox (1994) from using a property tax in the AJ model follow trivially, once it is recognised that the ROR-regulated monopoly faces the same incentives as the capital-subsidised monopoly;
- a post-tax cost of capital — rather than a pre-tax cost of capital — when combined with accelerated depreciation has the potential to increase investment in capital; and
- a regulator that is better at targeting the competitive outcome may not necessarily maximise social welfare under ROR regulation.

From the equivalent regime to the AJ model, an alternative model of ROR regulation was also designed. Although the model is slightly unrealistic, it derives a formula for the equivalent capital subsidy  $s$  that corresponds to any given fair rate of return  $f$  set by the regulator. Assuming Cobb-Douglas production technology and a linear industry demand curve, a numerical example was provided to illustrate the relationship between the equivalent capital subsidy and fair rate of return by the regulator. This highlighted

the paradoxical result established earlier that a lower fair rate set by the regulator is equivalent to a higher capital subsidy.

As economic students and practitioners tend to be more familiar with taxes and subsidies, rather than instruments of regulation, the equivalence result described here between the capital subsidy and fair rate, may be most useful as pedagogical tool for assisting in understanding the basic results and implications of the AJ model of ROR regulation.

The equivalence result established here is explored further in Chapter 3, to assess welfare in the AJ model of ROR regulation.

## CHAPTER 3: WELFARE UNDER ROR REGULATION

### 3.1 Introduction

This Chapter continues to analyse the AJ model of ROR regulation. The work here focuses upon the overall level of welfare derived under ROR regulation. In particular, a substantial portion of the Chapter is devoted to examining the production and allocative efficiency trade-off associated with setting the optimal fair rate of return.

#### 3.1.1 The Existing Literature on Welfare under ROR Regulation

Sheshinski (1971) was the first to address the issue of ROR regulation and its impact upon welfare in the AJ model. Importantly, he showed in a partial-equilibrium framework that:

- the introduction of ROR regulation leads to an unambiguous welfare gain;<sup>1</sup> and
- the welfare-maximising or optimal fair rate  $f^*$  lies within the range  $r_m > f^* > r$ , and involves setting a regulated price that is equal to the marginal cost of production to society.

The first result shows that even though ROR regulation leads to some level of production inefficiency, the outcome from having some small amount of ROR regulation in the industry will always be better than having no regulation whatsoever. The second result highlights that due to the input distortion, there is an interior solution for the optimal fair rate of return. This means that a welfare-maximising regulator will not want to set a fair rate that is equal to the normal rate of return on capital  $r$ . Further, while the optimal fair rate appears to yield a condition consistent with a first-best outcome, the inefficient over-capitalisation means that the marginal cost to society here, exceeds the efficient marginal cost of production.

The paper by Klevorick (1971) followed soon after the work of Sheshinski, and also addressed the issue of the optimal fair rate of return in a partial-equilibrium model. In contrast to Sheshinski though, Klevorick assumed that if the fair rate of return  $f$  were set

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<sup>1</sup> Sheshinski (1971) was able to make this assertion, because he had already assumed that capital was a normal factor of production. The importance of capital being a normal factor is highlighted in Section 3.2.

equal to  $r$ , the regulated monopoly would use an efficient input mix in the production of output. Subsequently, his analysis concluded that in addition to having an interior solution for  $f^*$ , it was possible that there would be an end-point solution for the optimal fair rate (i.e.  $f^* = r$ ).

Bailey (1973) provides a summary of the work done by Sheshinski and Klevorick. This links and clarifies their results for the optimal fair rate in the partial-equilibrium framework.<sup>2</sup> Importantly, it highlights the assumptions and cost conditions that are required to generate an interior and end-point solution for  $f^*$ . Bailey also extends the analysis, using a diagram to examine the optimal fair rate in a general-equilibrium framework.<sup>3</sup>

Callen, Mathewson and Mohrig (1974) undertake a thorough pseudo-empirical analysis of the AJ model of ROR regulation in a partial-equilibrium model. Their analysis is similar to the pseudo-empirical work done by Klevorick, as they also assume Cobb-Douglas production technology and a constant-elasticity demand curve for the industry. The numerical results derived for the optimal fair rate confirms the analytical results of Sheshinski (1971), Klevorick (1971) and Bailey (1973).

Yang and Fox (YF, 1994) investigate effect the introduction of a property tax — i.e. a capital tax — has upon welfare. Using an explicit social welfare function that is equal to the sum of consumer surplus, profit and tax revenue, the authors find that:

- the introduction of a capital tax has the potential to increase welfare in the AJ model; and
- a decrease in the fair rate has the same impact upon welfare as a decrease in an existing capital tax rate.

YF conclude (at page 59) that the first result “contradicts the long-established belief that a lower (or no) tax is preferred to a higher tax in maximising welfare”. According to the authors, the second result has the potentially interesting policy implication that, if the regulator misses the optimal fair rate by some amount  $-\Theta$ , then the tax authority could intervene and offset this outcome by raising the capital tax by an amount  $\Theta$ . They conclude (at page 66) however, that due to the different objectives that are likely to be

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<sup>2</sup> Page 104-7.

<sup>3</sup> See pages 108-110. Peles and Stein (1976) use a similar diagram in their general-equilibrium analysis at page 287.

faced by the relevant authorities “this offsetting policy is likely to be only a theoretical possibility”.

### 3.1.2 The Results and Contributions of this Chapter

This Chapter provides a number of insights into the impact ROR regulation has upon welfare, and the optimal fair rate of return that should be set by the regulator. It contributes to the existing literature by:

- using the equivalence result from Chapter 2 to establish a formal general-equilibrium (GE) model. This confirms the partial-equilibrium results of Sheshinski (1971), and extends his analysis by examining the outcome for the optimal fair rate when there is a distortion in a related market. The previous GE analysis done by Bailey (1973) and Peles and Stein (1976) used diagrams, and assumed there was no distortion in the related market;
- reconciling the different price-quantity diagrams used by Sheshinski (1971) and Waterson (1988) to highlight the impact ROR regulation has on the monopoly in a partial-equilibrium setting;
- linking the optimal capital subsidy  $s^*$  with the optimal fair rate of return  $f^*$ ; and
- outlining the precise conditions when the introduction of the capital tax used by YF (1994), increases and decreases welfare.

To undertake this analysis, the Chapter is structured as follows. Section 3.2 uses the equivalence result from Chapter 2 to set up a two-period-two-sector-single-person-general-equilibrium (GE) model of ROR regulation to examine the welfare results of Sheshinski (1971). Section 3.3 applies the methodology of Carlton (1979) to the AJ model to reconcile the different approaches that have been used to capture the impact of ROR regulation in a price-quantity diagram. In Section 3.4 the analysis of Bailey (1973) is reproduced to highlight the solutions for the optimal fair rate  $f^*$  under different assumptions and cost conditions. Section 3.5 revisits and modifies the alternative model of ROR regulation outlined in Section 2.6. From this, expressions are derived for the optimal fair rate  $f^*$  and the corresponding optimal capital subsidy  $s^*$ , and a numerical example is provided to assess welfare under optimal ROR regulation. In Section 3.6 the analysis from Section 3.4 is used to assess the welfare results of YF (1994). Section 3.7 summarises the key results of the Chapter.

## 3.2 A GE Model of Welfare Under ROR Regulation

This Section sets up a two-period-single-person-general-equilibrium (GE) model, which is used to derive the uncompensated welfare change that results from providing the monopoly with a capital subsidy. Subsequently, from the equivalence result of Chapter 2, this Section also analyses the impact ROR regulation has upon welfare in a GE framework. The previous GE analysis of ROR regulation done by Bailey (1973) and Peles and Stein (1976), used diagrams, rather than the formal framework that is outlined here.

Solving the GE model, an expression is derived for the dollar change in utility that arises when there is a policy change that affects the ROR-regulated or capital-subsidised monopoly, and there is an existing production tax distortion in the related competitive market. By assuming initially that there is either no related market effect, or no efficiency distortion in the related market, the partial-equilibrium welfare results of Sheshinski (1971) are derived. Removing these assumptions, the partial-equilibrium results are extended to the GE framework. This shows that if the product in the related competitive market is a complement (substitute), the regulator must set a lower (higher) fair rate than that recommended by Sheshinski.

The importance of the GE analysis established here is that in practice, it is likely there will be some related market effects and existing distortions in the regulation of public utilities. For example:

- substitutability occurs between products such as gas and electricity; and
- to cover the shared and common costs associated with networks, regulators often allow prices that are marked-up above the long-run marginal cost of providing the service.

### 3.2.1 Assumptions and Agents in the GE Framework

#### 3.2.1.1 *Assumptions of the Model*

As the model in this Section is different from that used throughout Chapter 2, there are some slight variations in the notation used here. The assumptions made in the GE model are that:

- there are only two periods — period 0 and period 1;



- in period 0 the consumer is endowed with an amount of good 0,  $\bar{x}_0$ . This can either be consumed in some quantity  $x_0$ , or invested and used as capital  $k$  in the production of output by the firms in the economy;
- the consumer price of good 0 —  $z_0$  — is equal to the producer price of good 0 —  $p_0$  — which is chosen as the numeraire (i.e.  $z_0 = p_0 = 1$ );
- in period 1, the consumer can consume leisure  $h$  for a maximum of  $T$  units of time. For each unit of the time ( $T - h$ ) that is supplied to the firms in this economy, a wage of  $w$  is paid;
- there are two industries in this economy. Both combine the units of labour  $n$  provided in period 1, with the units of capital  $k$  provided in period 0, to produce goods 1 and 2 in period 1;
- firm 1 is the ROR-regulated or capital-subsidised monopoly, that supplies the amount of good 1,  $q_1$ . The other industry is competitive,<sup>4</sup> and supplies an amount of good 2,  $q_2$ ;
- in period 1, goods 1 and 2 are consumed in the amounts  $x_1$  and  $x_2$ ;
- initially there is a production tax on both goods,  $t_i$ , where  $i = 1, 2$ . This drives a wedge between the present value of the relative price paid by the consumer —  $z_i$ ,  $i = 1, 2$  — and the relative price paid to producers in period 1 —  $p_i$ , where  $i = 1, 2$ . Subsequently, the present value of the relative prices faced by the consumer, will be,  $z_i = \frac{p_i + t_i}{1 + r}$ , where  $i = 1, 2$ .

These assumptions imply that in this economy, the *market clearing conditions* will be:

- **capital market** (which determines the user cost of capital  $r$ ):  $\bar{x}_0 - x_0 = k_1 + k_2$
- **goods market** (which determines the prices of goods 1 and 2,  $p_1$  and  $p_2$ ):  $x_1 = q_1$  and  $x_2 = q_2$ ; and
- **labour market** (which determines  $w$ ):  $T = h + n_1 + n_2$

### 3.2.1.2 The Consumer

The consumer aims to maximise their utility subject to the budget constraint. In this framework the consumer derives utility from consuming good 0 in period 0 (i.e.  $x_0$ ), and

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<sup>4</sup> The competitive industry in this GE framework is treated as if it is a single firm.

consuming leisure, good 1 and good 2 in period 1 (i.e.  $h, x_1, x_2$ ). Hence, the consumer's utility function is

$$U = U(x_0, h, x_1, x_2) \quad (3.2.1)$$

The value in period 0 of the total income  $I$  that the consumer derives over the two periods, consists of:

- the endowment of good 0 (i.e.  $\bar{x}_0$ );
- the present value of the wage income from supplying labour (i.e.  $\frac{w(T-h)}{1+r}$ );
- the present value of the profits derived by the monopolist (i.e.  $\pi_1$ ) and in the competitive industry (i.e.  $\pi_2$ ). The profits of both output markets are distributed to the consumer, who is also the sole shareholder; and
- the lump-sum transfers made to the consumer by the government (i.e.  $L$ ).

The value in period 0 of the expenditure  $E$  by the consumer over the two periods, consists of:

- the expenditure on units of good 0 consumed in period 0 (i.e.  $x_0$ ); and
- the present value of the expenditure on the units of goods 1 and 2 consumed in period 1 (i.e.  $z_i x_i, i = 1, 2$ ).

As all income is spent, the present value of the budget constraint is,

$$I = \bar{x}_0 + \frac{w(T-h)}{1+r} + \pi_1 + \pi_2 + L = x_0 + z_1 x_1 + z_2 x_2 = E \quad (3.2.2)$$

Hence, the individual consumer aims to

$$\begin{aligned} & \max_{x_0, h, x_1, x_2} U(x_0, h, x_1, x_2) \\ \text{s.t. } & \bar{x}_0 + \frac{w(T-h)}{1+r} + \pi_1 + \pi_2 + L = x_0 + z_1 x_1 + z_2 x_2 \end{aligned} \quad (3.2.3)$$

### 3.2.1.3 The Monopoly and Competitive Industry Profits

The monopoly receiving the per-unit capital subsidy  $s$ , where  $0 < s < 1$ , earns the level of profit  $\pi_1$ , which consists of:

- the present value of the operating profit from selling each unit of output  $q_1$  in period 1 at price  $p_1$  (i.e.  $\frac{p_1 q_1 - w n_1}{1+r}$ ); minus

- the cost of capital  $k_1$  that the firm borrows from consumers in period 0, and that is subsidised by the government (i.e.  $(1 - s)k_1$ ).

In the competitive industry profit  $\pi_2$  is earned, which consists of:

- the present value of the operating profit from selling each unit of output  $q_2$  in period 1 at price  $p_2$  (i.e.  $\frac{p_2 q_2 - wn_2}{1 + r}$ ); minus
- the cost of the capital  $k_2$ , which is borrowed from consumers in period 0.

Therefore the respective profits will be,

$$\text{Monopolist: } \pi_1 = \frac{p_1 q_1 - wn_1}{1 + r} - (1 - s)k_1, \text{ where } 0 < s < 1 \quad (3.2.4)$$

$$\text{Competitive: } \pi_2 = \frac{p_2 q_2 - wn_2}{1 + r} - k_2 \quad (3.2.5)$$

#### 3.2.1.4 The Government

The other agent in the economy is the government. The government has a budget  $G$  that consists of:

- the present value of the revenues from the production tax on goods 1 and 2 in period 1 (i.e.  $t_i q_i / (1 + r)$ ,  $i = 1, 2$ );
- the total cost of the capital subsidy payment made on the units of capital that are employed by the monopoly in period 0 (i.e.  $sk_1$ ); and
- the total lump-sum payments or transfers made to consumers  $L$ .

Thus, the government budget can be formally written as

$$G = \frac{t_1 q_1}{1 + r} + \frac{t_2 q_2}{1 + r} - sk_1 - L \quad (3.2.6)$$

### 3.2.2 The Conventional Welfare Equation

To derive an expression that captures the impact a change in government policy has upon welfare, the conventional Harberger (1971) analysis is used. This involves the government making a lump-sum transfer that balances the budget, and the welfare effects of this transfer then being examined. Sieper (1981) and Jones (2001, 2003) provide expositions of the working that is required to derive such an expression for the welfare equation.

Assuming initially that there is no change in production taxes (i.e.  $dt_1 = dt_2 = 0$ ), and later, that there is no production tax on the ROR-regulated or capital-subsidised monopoly (i.e.  $t_1 = 0$ ); the *conventional welfare equation*<sup>5</sup> derived from following the methodology of Sieper and Jones is then,

$$\boxed{\frac{dU}{\lambda} = -\frac{q_1}{1+r}dp_1 - sdk_1 + \frac{t_2}{1+r}dq_2} \quad (3.2.7)$$

The working to obtain the outcome in equation (3.2.7) is outlined in the Appendix of the Chapter in Section A.3.1.

As the Lagrange multiplier  $\lambda$  is the marginal utility of income to the consumer, the expression in equation (3.2.7) represents the dollar change in utility that is experienced by a consumer as a result of any change in government policy, and captures the uncompensated welfare change. It shows that welfare:

- rises by the extra tax revenues derived from the competitive industry (i.e.  $\frac{t_2}{1+r}dq_2$ );
- and
- falls by the extra subsidy payment made to the monopoly as it employs more units of capital (i.e.  $sdk_1$ ), and by the increase in price charged by the monopoly (i.e.  $\frac{q_1}{1+r}dp_1$ ).

It is well established in the welfare economics literature, that in a GE framework, any welfare change can be captured over a change in the level of output or activity in the industry (i.e.  $dq_i$ 's). The reason for this is that the impact any change in government policy has upon welfare is reflected by the effect it has on the utility of the consumer, and the consumer's level of utility depends upon its consumption of output. Consequently, it should be possible to convert the expression in equation (3.2.7) to reflect such an outcome.

The FOC for the capital-subsidised monopoly given by equation (A3.1.9) is

$$\frac{p_1}{1+r}dq_1 + \frac{q_1}{1+r}dp_1 - \frac{w}{1+r}dn_1 - (1-s)dk_1 = 0$$

This can be rewritten as,

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<sup>5</sup> This terminology is used in the analysis of Jones (2001) at page 5 and Jones (2003) at page 7.

$$-\frac{q_1}{1+r}dp_1 = \frac{p_1}{1+r}dq_1 - \frac{w}{1+r}dn_1 - (1-s)dk_1 \quad (3.2.8)$$

Where superscript 0 is used to denote the present value of various terms here (e.g.  $p_1/1+r = p_1^0$ ), the present value of the private marginal cost of production that is faced by the monopolist receiving the capital subsidy  $s$  is,

$$MC_{s1}^0 = \frac{w}{1+r} \frac{\partial n_1}{\partial q_1} + (1-s) \frac{\partial k_1}{\partial q_1} \quad (3.2.9)^6$$

As this marginal cost takes into account the way in which capital and labour adjust when the output of firm 1 increases, the marginal cost of either factor is the same, and equation (3.2.9) is also equal to both the marginal labour cost ( $MLC_1$ ) and marginal capital cost ( $MKC_1$ ).

From equation (3.2.9), equation (3.2.8) simplifies to

$$-\frac{q_1}{1+r}dp_1 = (p_1^0 - MC_{s1}^0)dq_1 \quad (3.2.10)$$

Therefore, the dollar change in utility can be expressed as

$$\boxed{\frac{dU}{\lambda} = (p_1^0 - MC_{s1}^0)dq_1 - sdk_1 + t_2^0 dq_2} \quad (3.2.11)$$

The private marginal cost  $MC_{s1}^0$  of the capital-subsidised monopoly, or alternatively the marginal labour cost  $MLC_1$  of the ROR-regulated monopoly, determines the level of output produced by the firm. This is because the capital-subsidised monopolist continues to employ capital and labour until marginal revenue is equal to the private marginal cost of production in the presence of the capital subsidy; or the ROR-regulated monopoly continues to employ capital and labour until the marginal revenue is equal to the private marginal labour cost in the presence of a given fair rate. While the private marginal cost curves can be used to do positive analysis, to undertake welfare analysis and capture the true resource cost to society, it is necessary to derive the marginal cost to society in the presence of a capital subsidy or ROR regulation.

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<sup>6</sup> Although the partial derivative notation is used in the expressions for the various marginal costs, in the GE framework, these partial derivative terms do not have the standard interpretation. The reason for this is that in these partial derivatives, the endogenous variables of the wage rate, the output price and the rate of return, are no longer held constant. In the GE model these terms are all changing in order to clear the respective goods, capital and labour markets.

The present value of the marginal cost of production to society in the presence of the capital subsidy or fair rate is,

$$MC_{R1}^0 = \frac{w}{1+r} \frac{\partial n_1}{\partial q_1} + \frac{\partial k_1}{\partial q_1} > MC_{e1}^0 \quad (3.2.12)$$

This marginal cost is higher than the efficient marginal cost for firm 1  $MC_{e1}^0$ , due to the distortionary impact the capital subsidy has on the input mix used to produce output. From equation (3.2.12) it follows that equation (3.2.8) can be rewritten to give,

$$-\frac{q_1}{1+r} dp_1 - s dk_1 = (p_1^0 - MC_{R1}^0) dq_1 \quad (3.2.13)$$

Substituting equation (3.2.13) into equation (3.2.7), yields an expression for the welfare equation, which gives the dollar change in utility over a change in the level of output or activity in the industry i.e. some  $dq_i$  term, where  $i = 1, 2$ . That is,

$$\boxed{\frac{dU}{\lambda} = (p_1^0 - MC_{R1}^0) dq_1 + t_2^0 dq_2} \quad (3.2.14)$$

### 3.2.3 The Welfare Effect of Changing the Capital Subsidy or Fair Rate

As the terms in equation (3.2.14) are all a function of the capital subsidy  $s$ , the following welfare equation can be derived.

$$\boxed{W_s = \frac{dU}{ds} \frac{1}{\lambda} = (p_1^0 - MC_{R1}^0) \frac{\partial q_1}{\partial s} + t_2^0 \frac{\partial q_2}{\partial s}} \quad (3.2.15)^7$$

This gives the welfare effect of a change in the specific capital subsidy, or alternatively, from adjusting the fair rate under ROR regulation. The expression in equation (3.2.15) is used here to initially illustrate the welfare result established in the partial-equilibrium analysis of Sheshinski (1971), and then to extend these results to a GE framework.

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<sup>7</sup> The partial derivative expressions on the right-hand side of equation (3.2.15) are true partial derivatives. The reason for these terms is that, the total differential terms in the welfare equation are initially expressed for some undefined change in government policy. Hence, until the policy change is defined as being a change in the capital subsidy, the effect of the capital subsidy upon output is only one term in the expression for  $dq_i$ ,  $i = 1, 2$ , e.g.  $dq_i = \frac{\partial q_i}{\partial s} ds + \dots$ . Once it is established that the impact of the capital subsidy upon welfare is being examined, the expression in equation (3.2.14) is equal to:

$$\frac{dU}{\lambda} = (p_1^0 - MC_{R1}^0) \frac{\partial q_1}{\partial s} ds + t_2^0 \frac{\partial q_2}{\partial s} ds$$

Dividing through by  $ds$ , the expression for the welfare equation in (3.2.15) is derived.

### 3.2.3.1 The Partial-Equilibrium Analysis of Sheshinski (1971)

Sheshinski (1971) examined welfare under ROR regulation in a partial-equilibrium framework and found that:

- “some regulation via the fair rate of return is always advantageous”;<sup>8</sup> and
- there is an interior solution for the optimal fair rate  $f^*$  (i.e.  $r_m > f^* > r$ ), and at this fair rate the ROR-regulated price is set equal to the distorted marginal cost of production faced by society.<sup>9</sup>

The GE framework outlined here can be modified to illustrate the partial-equilibrium results of Sheshinski, if it is assumed that there is either:

- no cross-price effect (i.e.  $\partial q_2 / \partial s = 0$ ); or
- no existing distortion in the related competitive market (i.e.  $t_2 = 0$ ).

Setting  $\partial q_2 / \partial s$  or  $t_2$  equal to zero, the welfare equation (3.2.15) simplifies to,

$$W_s = \frac{dU}{ds} \frac{1}{\lambda} = (p_1^0 - MC_{R1}^0) \frac{\partial q_1}{\partial s} \quad (3.2.16)$$

To establish that some capital subsidy or ROR regulation is beneficial to society, it is necessary to evaluate the outcome in equation (3.2.16) when there is no capital subsidy (i.e.  $s = 0$ ), or the fair rate is set equal to the monopoly rate of return (i.e.  $f = r_m$ ).

When there is no capital subsidy or the fair rate is ineffective, firm 1 will charge the unregulated monopoly price of  $p_{m1}^0$ . As there is also no input distortion in these circumstances, the private and social marginal cost for the firm will be equal to the efficient marginal cost  $MC_{e1}^0$ , and the expression for equation (3.2.16) when  $s = 0$  is,

$$W_s|_{s=0} = (p_{m1}^0 - MC_{e1}^0) \frac{\partial q_1}{\partial s} \quad (3.2.17)$$

The sign of equation (3.2.17) now depends on the sign of  $\partial q_1 / \partial s$ .

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<sup>8</sup> Sheshinski (1971) at page 175.

<sup>9</sup> Bailey (1973) illustrates that while the analysis of Sheshinski is not incorrect, there are instances when there should be an end-point solution for the optimal fair rate — i.e.  $f^* = r$ . The circumstances where an end-point and interior solution exists for the optimal fair rate are explored in Section 3.4. For the purposes of the analysis in this Section only the interior solution of Sheshinski is examined, and the adjustment that needs to be made to this interior solution in the GE framework.

The level of welfare here is maximised by setting equation (3.2.16) — which captures marginal welfare gain from a change in the subsidy — equal to zero, and solving for the price. Therefore, the optimal capital subsidy  $s^*$ , and the corresponding optimal fair rate  $f^*$  must be set in period 0 so that in period 1,

$$p_{R1}^* = MC_{R1} \quad (3.2.18)^{12}$$

This is the condition found by Sheshinski, and as he points out (at page 177) it “resembles the standard optimality rule” of setting price equal to the social marginal cost of production. However, because of the input distortion associated with ROR regulation, the social marginal cost of production faced by the monopolist here in period 1 —  $MC_{R1}$  — exceeds the efficient marginal cost of production —  $MC_{e1}$ . The result in equation (3.2.18) is perhaps most appropriately described as an example of a “second-best efficient” outcome.<sup>13</sup> That is, it represents the best outcome for society, given the constraint that, the government or regulator has committed to providing the monopoly with an input-distorting capital subsidy or fair rate of return. The outcome in period 1 from setting the optimal fair rate  $f^*$  or capital subsidy  $s^*$  in period 0, is illustrated in Figure 3.2.2.

The diagram highlights the relationship between:

- the private marginal cost of production faced by the capital-subsidised monopoly at the optimal capital subsidy  $s^*$  — i.e.  $MC_{s1}(s^*)$  — or alternatively, the marginal labour cost faced by the ROR-regulated monopoly at the corresponding optimal fair rate  $f^*$  — i.e.  $MLC_1(f^*)$ . It depicts the outcome described in equation (3.2.9);

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<sup>12</sup> As it is assumed here that there is an interior solution for  $f^*$  at price  $p_{R1}^*$ , the distorted marginal cost  $MC_{R1}$  exceeds the distorted average cost of production  $AC_{R1}$ , and the ROR-regulated monopoly earns greater than zero profit. If  $AC_{R1}$  were instead greater than or equal to  $MC_{R1}$ , then the marginal cost-based price will no longer yield greater than zero profits. Although not considered here, Section 3.4 outlines that such an outcome leads to an end-point solution for the optimal fair rate i.e.  $f^* = r$ .

<sup>13</sup> Lipsey and Lancaster (1956-7) coined the phrase “second-best efficiency”. Their theory of second best was based around finding an efficient price in a market, given that there was an existing distortion in a related market. Specifically, they examined the optimal price that should be charged for a public utility’s output, where it was a substitute for a product provided by a private monopoly. However, more recently, the term second-best efficiency has been used to describe instances where the best possible outcome for society is achieved, given some existing distortion and no related market effects. An example of this more liberal usage of the term is found in the context of the natural monopoly problem, where a marginal-cost-based price fails to recover cost. There, the term “second best” has been used to describe a Ramsey-Boiteux price, which represents the linear-pricing regime that maximises efficiency, given that there is some revenue requirement placed upon the firm preventing a first-best outcome. It is this more liberal usage of the term that is relied upon here to describe the condition in equation (3.2.18) as being second best.



The level of welfare here is maximised by setting equation (3.2.16) — which captures marginal welfare gain from a change in the subsidy — equal to zero, and solving for the price. Therefore, the optimal capital subsidy  $s^*$ , and the corresponding optimal fair rate  $f^*$  must be set in period 0 so that in period 1,

$$p_{R1}^* = MC_{R1} \quad (3.2.18)^{12}$$

This is the condition found by Sheshinski, and as he points out (at page 177) it “resembles the standard optimality rule” of setting price equal to the social marginal cost of production. However, because of the input distortion associated with ROR regulation, the social marginal cost of production faced by the monopolist here in period 1 —  $MC_{R1}$  — exceeds the efficient marginal cost of production —  $MC_{e1}$ . The result in equation (3.2.18) is perhaps most appropriately described as an example of a “second-best efficient” outcome.<sup>13</sup> That is, it represents the best outcome for society, given the constraint that, the government or regulator has committed to providing the monopoly with an input-distorting capital subsidy or fair rate of return. The outcome in period 1 from setting the optimal fair rate  $f^*$  or capital subsidy  $s^*$  in period 0, is illustrated in Figure 3.2.2.

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<sup>12</sup> As it is assumed here that there is an interior solution for  $f^*$  at price  $p_{R1}^*$ , the distorted marginal cost  $MC_{R1}$  exceeds the distorted average cost of production  $AC_{R1}$ , and the ROR-regulated monopoly earns greater than zero profit. If  $AC_{R1}$  were instead greater than or equal to  $MC_{R1}$ , then the marginal cost-based price will no longer yield greater than zero profits. Although not considered here, Section 3.4 outlines that such an outcome leads to an end-point solution for the optimal fair rate i.e.  $f^* = r$ .

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- the social marginal cost of production for any given level of the capital subsidy  $s$  or fair rate  $f$  — i.e.  $MC_{s1}(\forall s, f)$ . It is described by the outcome in equation (3.2.12); and
- the efficient marginal cost of production — i.e.  $MC_{e1}$ . This is the outcome for equation (3.2.12) when there is either no capital subsidy provided (i.e.  $s = 0$ ) or the fair rate is set equal to the rate of return earned by the unregulated monopoly (i.e.  $f = r_m$ ).

**FIGURE 3.2.2 THE WELFARE-MAXIMISING CAPITAL SUBSIDY OR FAIR RATE**

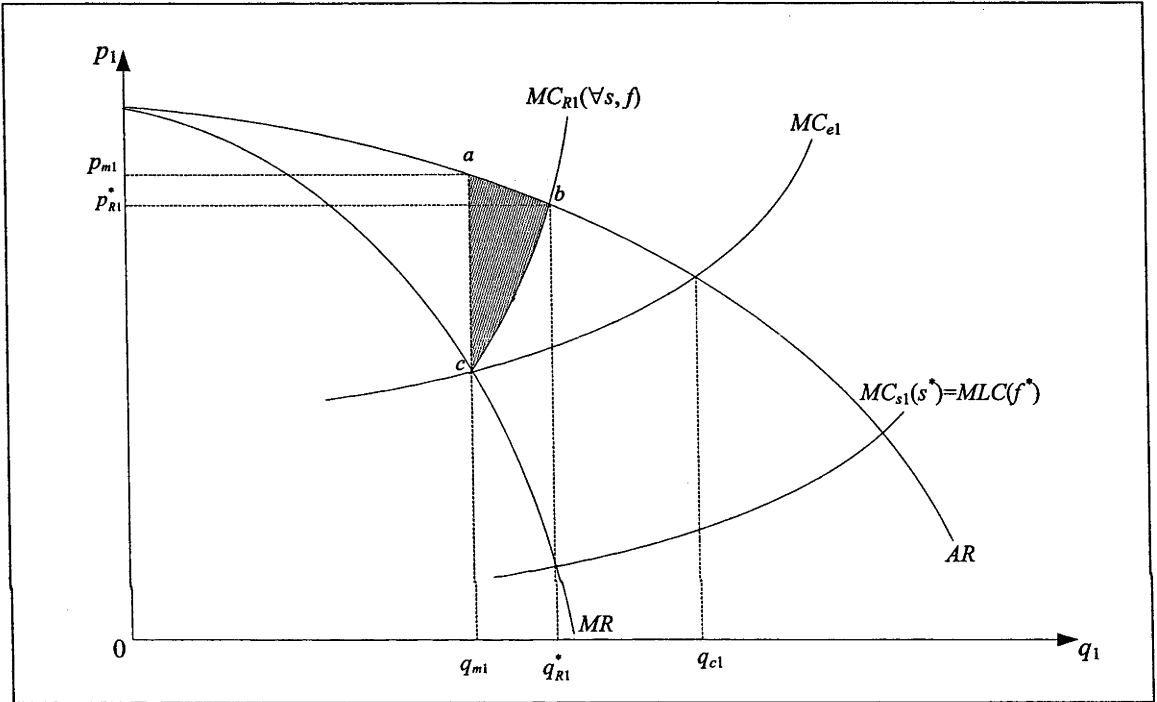


Figure 3.2.2 illustrates that the private marginal cost of production for the capital-subsidised monopoly, or the marginal labour cost of production for the ROR-regulated monopoly, lies below both the efficient and social marginal cost curves —  $MC_{e1}$  and  $MC_{R1}$ . As the firm continues to produce until marginal revenue  $MR$  equals the private marginal cost of production  $MC_s(s^*)$  or the marginal labour cost  $MLC(f^*)$ , the optimal ROR-regulated or capital-subsidised monopoly supplies  $q_{R1}^*$  units of output.

The input distortion here implies that as shown by Sheshinski (in Figure 1, page 177), the social marginal cost  $MC_{R1}$  lies above the efficient marginal cost of production  $MC_{e1}$ , for all level of output greater than  $q_{m1}$ . Further, this leads to the monopolist increasing output from  $q_{m1}$  to  $q_{R1}^*$ , which is less than the Pareto-optimal level of output  $q_{c1}$ . The resulting welfare gain from the increase in output that is induced by imposing the

optimal fair rate  $f^*$ , or providing the optimal capital subsidy  $s^*$ , is captured in Figure 3.2.2 by the shaded area  $abc$ .

### 3.2.3.2 The GE Analysis of the Optimal Capital Subsidy or Fair Rate

Substitutability and complementarity between products, and irremovable distortions, appear to exist in a number of public utility industries. For example there is substitutability in gas and electricity consumption, and regulators allow many networks to price above long-run marginal cost, to account for the shared or common costs that cannot be attributed to any particular service.<sup>14</sup> Therefore, when considering ROR regulation, it seems useful to consider the optimal fair rate where there are existing distortions in related markets. Such an outcome can be captured using the GE model established in this Section.<sup>15</sup>

By examining the impact of introducing capital subsidies on two monopolists, the GE framework can be used to analyse the condition for the optimal fair rate when there is a related ROR-regulated monopoly market. Alternatively, the equivalence between price regulation and the monopoly receiving the production subsidy, (outlined in Section 2.5), could be adapted to analyse the impact ROR regulation has, when the monopoly in the related market is subject to price regulation.

Equation (3.2.15) describes the dollar change in utility that occurs from changing a specific capital subsidy or fair rate, when there is an existing production tax distortion in a related competitive market. The outcome given by equation (3.2.15) can be illustrated using the diagram in Figure 3.2.3.

If it is assumed capital is a normal input (i.e.  $\partial q_1/\partial s > 0$ ), then in period 1, the marginal welfare gain in market 1 from decreasing the existing fair rate or increasing the existing capital subsidy in period 0 —  $(p_{R1} - MC_{R1})(\partial q_1/\partial s)$  — will be equal to the vertical sliver

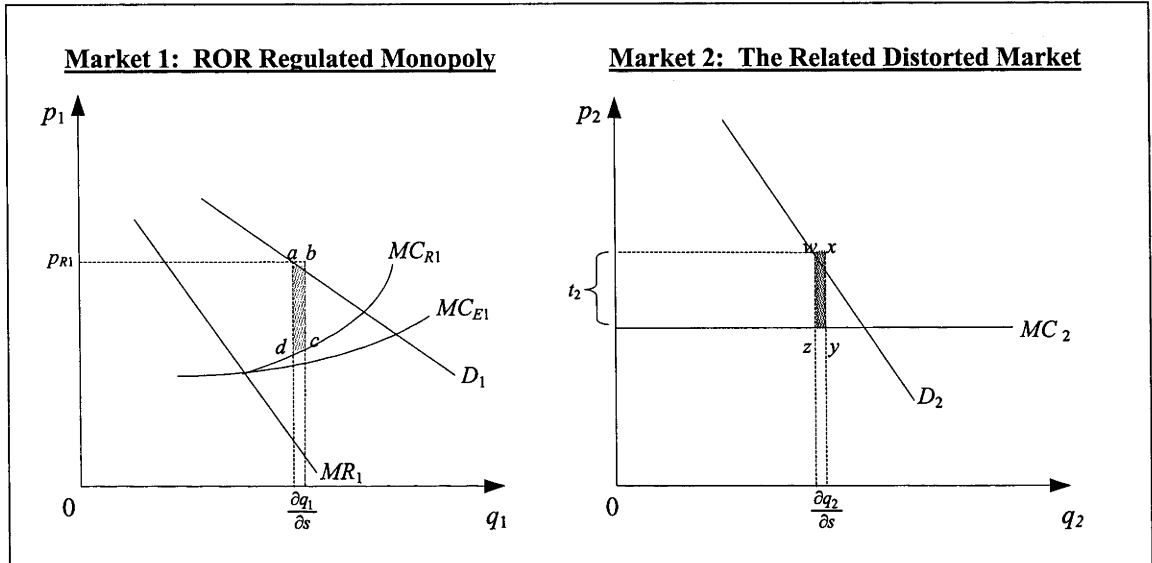
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<sup>14</sup> For example, in both the US and Australian telecommunications markets, the regulator allows an access price for the network that is set above the estimate for the long-run marginal cost. This is done to account for common costs of the network.

<sup>15</sup> The analysis of Bailey was more concerned with highlighting that in a GE framework, there was an additional exchange efficiency consideration to take into account. Further, unlike the analysis done here, which only examines the Sheshinski outcome where there is an interior solution for the optimal fair rate, Bailey outlines that it is also possible for there to be an end-point solution for the optimal fair rate when there is no existing distortion in the competitive industry. She establishes (at page 108) that such an outcome will arise if “society rates the output of the monopoly very highly relative to the competitive output”. As Bailey notes, this means “society is willing to trade the monopoly good for the competitive good even when the (production) inefficiency imposed is very great.”

*abcd*. However, unlike the partial-equilibrium framework, this does not capture the total marginal welfare change. The cross-price effect in the related market with the existing production tax, means that in period 1 there is now an additional marginal welfare change that must be assessed —  $t_2(\partial q_2/\partial s)$ . This term is depicted in the diagram by the vertical sliver *wxyz*.

**FIGURE 3.2.3 ROR REGULATION WITH A RELATED DISTORTED MARKET**



To find the welfare-maximising condition that the optimal fair rate and capital subsidy must satisfy, equation (3.2.15) is set equal to zero. This yields the following expression for the welfare-maximising price  $p_{R1}^*$  that should be charged in period 1,

$$p_{R1}^* = \underbrace{MC_{R1}}_{>0} + \underbrace{\sigma t_2}_{>0}, \text{ where } \sigma = -\frac{\partial q_2/\partial s}{\partial q_1/\partial s} \quad (3.2.19)$$

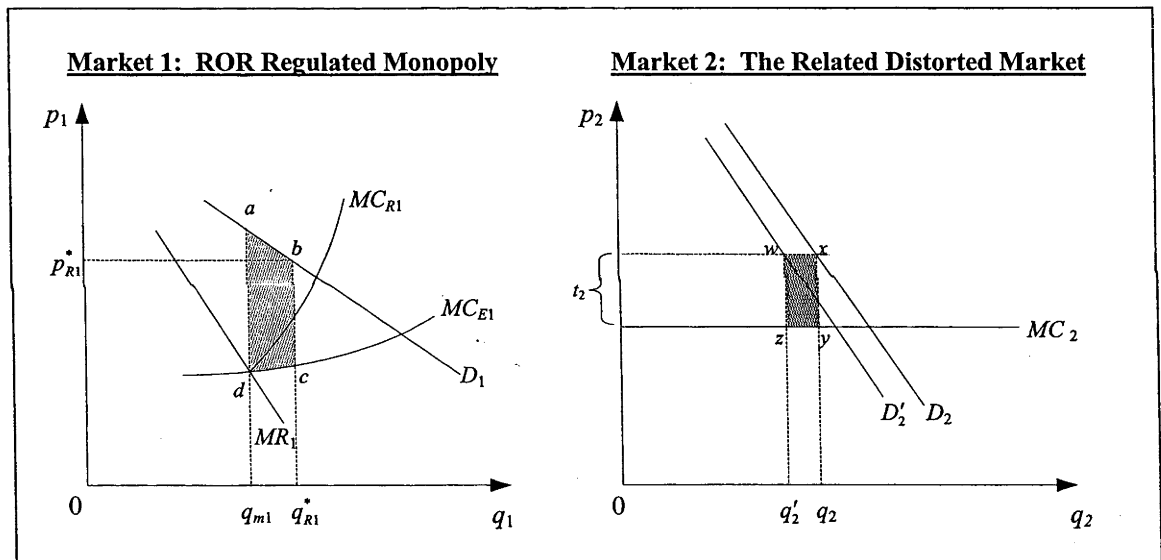
As it is assumed there are now cross-price effects, it is apparent from equation (3.2.19) that the distorted-marginal-cost pricing recommended in the partial-equilibrium analysis of Sheshinski, will no longer be optimal.<sup>16</sup> From equation (3.2.19), the relationship between the optimal price  $p_{R1}^*$ , and the distorted marginal cost  $MC_{R1}$  in the regulated market, depends upon the sign of the term  $\sigma$ . This term reflects, the substitutability in

<sup>16</sup> The idea that marginal-cost pricing is not optimal when there is an irremovable distortion in a related market, is consistent with the theory of second best outlined by Lipsey and Lancaster (1956-57). In their analysis however, they did not consider the impact input distortions would have on the social marginal cost of production.

consumption between the output in the related market, and the product supplied by the ROR-regulated monopoly.

Where  $\sigma > 0$ , then  $\partial q_2 / \partial s < 0$ , and the product in the related market with the irremovable distortion (in the form of the production tax), is a substitute. The welfare gain in the ROR-regulated market here must be traded-off against a Harberger (1971) rectangle welfare loss in the related market. Consequently, the optimal price  $p_{R1}^*$  charged in the ROR-regulated must now be set above the distorted marginal-cost  $MC_{R1}$ , and the optimal fair rate  $f^*$  here will be higher than that recommended by Sheshinski. This outcome is illustrated in Figure 3.2.4, where the welfare gain in the ROR-regulated market is equal to area  $abcd$ , and the Harberger rectangle welfare loss is equal to area  $wxyz$ .

**FIGURE 3.2.4 ROR REGULATION WITH A SUBSTITUTE PRODUCT**



Where  $\sigma < 0$ , then  $\partial q_2 / \partial s > 0$ , and the output in the related market is a complement. This implies that the welfare gain in the ROR-regulated market is now reinforced by a Harbeger rectangle welfare gain. The optimal price  $p_{R1}^*$  charged in the ROR-regulated market must now be set below the distorted marginal cost  $MC_{R1}$ , and the optimal fair rate  $f^*$  will be lower than that recommended by Sheshinski.<sup>17</sup>

<sup>17</sup> As the ROR-regulated monopoly cannot operate if  $f^*$  is set below  $r$ , it assumed here that the resulting optimal fair rate in the GE framework must still be greater-than-or-equal to the normal rate of return on capital  $r$ . Alternatively, the optimal price will be greater-than-or-equal to the distorted average cost of production  $AC_{R1}$ .

As the remaining work in this Chapter only examines the optimal fair rate in a partial-equilibrium framework, the subscripts and superscripts used in this GE model are dropped in the analysis that follows. These Sections revert back to using the simple notation that was employed throughout the course of Chapter 2.

### 3.3 Depicting ROR Regulation in a Price-Quantity Diagram —

#### Sheshinski (1971) versus Waterson (1989)

The price-quantity diagrams used by Sheshinski (1971) and Waterson (1989) to portray the impact of ROR regulation on the monopolist appear very different. In the diagram of Sheshinski at page 177, the welfare change is depicted by an area lying above the additional units of output supplied under ROR regulation. In contrast, the diagram of Waterson at page 88, captures the welfare change, by subtracting an area lying above the units of output originally supplied by the unregulated monopoly, from an area lying over the additional units of output supplied as a result of ROR regulation.

This Section reconciles the two approaches used by Sheshinski and Waterson. It highlights that the different areas arise due to the different social marginal cost curves used by the authors. The social marginal cost curve of Sheshinski is drawn for all levels of the fair rate (i.e.  $\forall f$ ), while the social marginal cost curve of Waterson is drawn for a given level of the fair rate (i.e.  $f = f_0$ ). The analysis of Waterson is consistent with diagrammatic framework employed by Carlton (1979), which examined the impact of an input tax. In this diagrammatic framework, the inefficiency arising from the AJ effect can be categorised as an example of what Carlton referred to as a production-deadweight-loss “banana”. Subsequently the price-quantity diagram of Waterson illustrates that ROR regulation involves a welfare trade-off between a Carlton production-deadweight-loss banana, and an area that captures the standard allocative efficiency gain from an increase in output.

#### 3.3.1 Bananas, Boxes and The Marginal Cost Curves of Carlton

Carlton (1979) showed how the positive and normative impact of an input-market distortion in an industry could be illustrated in the price-quantity space.<sup>18</sup> The specific input market distortion Carlton examined, was an input tax levied on a competitive factor of production that was used to produce output in a competitive market. By deriving the private marginal cost curve faced by the firm, Carlton obtained the level of

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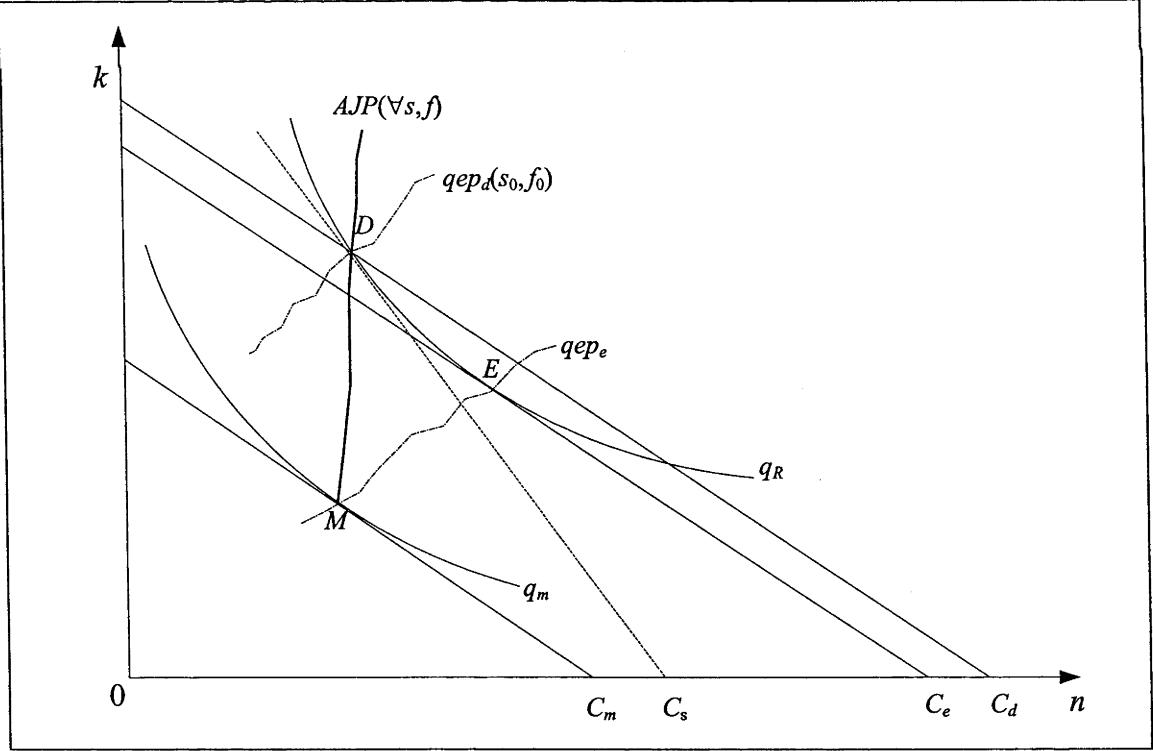
<sup>18</sup> Albon (1998) provides a good exposition of the methodology used by Carlton when he examines the welfare impact of the removal of the Diesel Fuel Rebate Scheme in Australia.

production in the industry. By deriving the distorted social marginal cost curve, Carlton showed the normative or welfare impact of the input tax.

A feature of the distorted-social-marginal-cost curve was that, the increase in the cost to society from the input distortion was captured in the price-quantity space by what Carlton described as a “banana-” and “box-shaped” area. Although Waterson (1989) does not draw any link to the formal analysis of Carlton, in his diagram illustrating the impact ROR regulation has on the monopoly, he implicitly employs a social marginal cost curve which has identical characteristics to that used by Carlton.

To show that a banana- and box-shaped area captures the overall change in the cost to society under ROR regulation, and to reconcile the diagram of Waterson with the diagram of Sheshinski, it is first necessary to derive the marginal cost curves used by Carlton. As in Albon (1998), this is done, by using the information contained about the total cost of production in the input-space diagram of Figure 3.3.1. To simplify the analysis in this Section it is assumed throughout that the firm is subject to constant-returns-to-scale production technology.<sup>19</sup>

FIGURE 3.3.1 THE TOTAL COST OF PRODUCTION IN THE INPUT SPACE

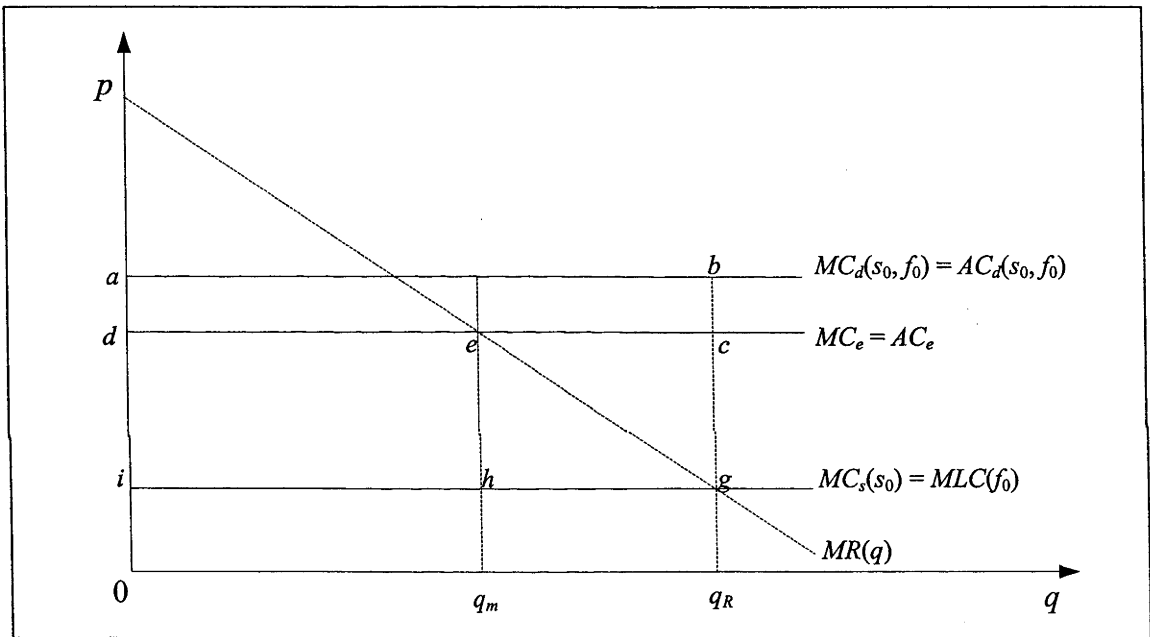


<sup>19</sup> An implication of constant-returns-to-scale technology is that both factors of production are normal, so output will always increase with the introduction of ROR regulation or an equivalent capital subsidy.



In Figure 3.3.1,  $M$  denotes the efficient input mix used by the unregulated monopoly to produce the level of output  $q_m$ , at a cost to the firm and society of  $C_m$ . When the monopoly is granted the input subsidy on capital  $s_0$ , or subject to the regulated fair rate of return  $f_0$ , the firm increases its level of production to  $q_R$  units of output. However, because under each regime the monopoly employs the distorted input mix at point  $D$ , the firm inefficiently over-capitalises in its production, which leads to the social cost of production  $C_d$  exceeding the efficient cost of production  $C_e$ . While the ROR-regulated monopoly actually faces this social cost of production  $C_d$ , the capital-subsidised monopoly incurs the lower private cost of production  $C_s$ .

**FIGURE 3.3.2 THE MARGINAL COST CURVES OF CARLTON**



As this is a long-run model and there are no shared or common costs of production, the assumption of constant returns guarantees that the marginal and average cost curves will be constant and equal to one another. Hence, each of the costs shown in the input-space diagram of Figure 3.3.1 will correspond in the price-quantity space, to an area under the average or marginal cost curves for the levels of output  $q_m$  and  $q_R$ . That is, in Figure 3.3.2:

- the area under  $MC_e$  at output  $q_m$  — area  $deq_m0$  — is equal to  $C_m$  and the area under  $MC_e$  at output  $q_R$  — area  $dcq_R0$  — is equal to  $C_e$ ;
- the area under  $MC_d(s_0, f_0)$  at output  $q_R$  — area  $abq_R0$  — is equal to  $C_d$ ; and
- the area under  $MC_s(s_0)$  or  $MLC(f_0)$  at output  $q_R$  — area  $igq_R0$  — is equal to  $C_s$ .

Aside from the areas underneath the marginal cost curves corresponding to total costs, the three marginal cost curves used by Carlton — depicted in Figure 3.3.2 — have some very important and distinctive properties. For example:

- the marginal cost curve  $MC_e$  corresponds to the marginal cost of production along the cost-minimising, or efficient, output expansion path  $qep_e$ ;
- the marginal cost curve  $MC_d(s_0, f_0)$  corresponds to the social marginal cost of production along the inefficient output expansion path drawn for the given input subsidy on capital  $s_0$ , or the given fair rate of return  $f_0$  — i.e.  $qep_d(s_0, f_0)$ . As the distorted marginal cost curve  $MC_d(s_0, f_0)$  reflects an inefficient input mix, it exceeds the efficient marginal cost curve  $MC_e$  over all levels of output  $q$  in the price-quantity space. The importance of the distorted marginal cost curve is that it can be used to undertake the welfare analysis resulting from ROR regulation or a capital subsidy. This is the social marginal cost curve implicitly used by Waterson (1989); and
- the marginal cost curve  $MC_s(s_0)$  corresponds to the private marginal cost of production faced by the monopoly receiving the capital subsidy  $s_0$ . For the regulated monopoly subject to the equivalent fair rate of return  $f_0$ , this marginal cost curve is identical to the marginal labour cost curve  $MLC(f_0)$ . The importance of these identical marginal cost curves,  $MC_s(s_0)$  and  $MLC(f_0)$ , is that both can be used to undertake positive analysis of the industry. For example, in order for the capital-subsidised monopoly to maximise profit, the level of output produced  $q_R$ , is determined by the point where the private marginal cost curve  $MC_s(s_0)$  intersects the marginal revenue curve  $MR(q)$ . Meanwhile, in order for the ROR-regulated monopoly to maximise the total allowed return on capital — which subsequently maximises the regulated firm's profits — the level of output produced  $q_R$ , will be determined by the point where the marginal labour cost curve  $MLC(f_0)$  intersects the marginal revenue curve  $MR(q)$ .

Using the information about the respective costs of production represented by the areas underneath the marginal cost curves, it is possible to conclude that in the price-quantity diagram, for the monopoly receiving the capital subsidy  $s_0$ :

- area  $abgi$  corresponds to the total subsidy payment made to the monopoly  $C_d - C_s$ ;
- area  $abcd$  corresponds to the production inefficiency  $C_d - C_e$  that arises from the over-capitalising in producing  $q_R$  units of output; and
- area  $dcgi$  is therefore the “net-subsidy” payment made by the Government to the monopoly.

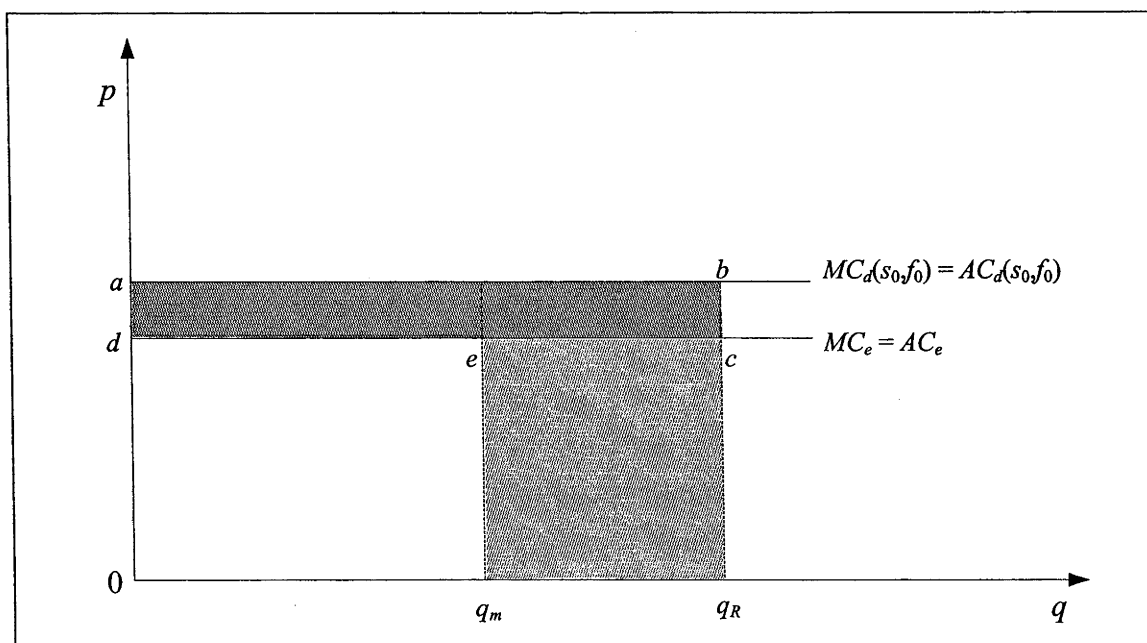
Meanwhile, for the ROR-regulated monopoly subject to the equivalent fair rate  $f_0$ :

- area  $abcd$  corresponds to the production inefficiency  $C_d - C_e$ , which is a cost that is borne by the ROR-regulated monopoly.

In addition to this, it is now possible to show that, the increase in the total cost to society arising from the capital subsidy or regulated fair rate, can be captured in the price-quantity space by what Carlton refers to as a “banana”- and “box”-shaped area. That is, in Figure 3.3.2, the change in the total social cost of production is equal to area  $abcd$  plus  $ecq_Rq_m$ , where:

- area  $abcd$  is the increase in the cost to society arising from using a distorted input mix to produce the  $q_R$  units of output. It is the area Carlton (1979) referred to as a banana-shaped area,<sup>20</sup> and it captures the production deadweight loss resulting from the inefficient over-capitalisation in production. Consequently, the inefficiency arising from the AJ effect, can be categorised as one example of the Carlton production-deadweight-loss banana; and
- area  $ecq_Rq_m$  is the increase in the efficient cost incurred as a result of increasing the level of production from  $q_m$  to  $q_R$ . It is what Carlton referred to as the box-shaped area.

FIGURE 3.3.3 THE INCREASE IN PRODUCTION COST USING A BANANA AND BOX



<sup>20</sup> This area will more closely resemble a banana shape when there is an increasing or decreasing marginal cost curve.

To highlight the increase in the social cost of production arising from following the methodology of Carlton for the ROR-regulated monopoly or capital-subsidised monopoly, Figure 3.3.2 is redrawn. In Figure 3.3.3, the dark-shaded area  $abcd$  captures the Carlton banana, while the light-shaded area  $ecq_Rq_m$  captures the Carlton box.

As the only difference between the outcomes under ROR regulation and the equivalent capital subsidy is in relation to distribution, to avoid any unnecessary repetition throughout the remainder of this Section, only the outcome under ROR regulation is considered.

### 3.3.2 The Social Marginal Cost Curves of Carlton and Sheshinski

For simplicity, throughout the remainder of this Chapter, the different social marginal cost curves used in the diagrams of Sheshinski (1971) and Waterson (1989) to analyse ROR regulation, are referred to respectively as the Sheshinski social marginal cost curve, and the Carlton social marginal cost curve.

In Section 3.3.1, it was established that under ROR regulation, the Carlton social marginal cost curve, implicitly used in the price-quantity diagram of Waterson:

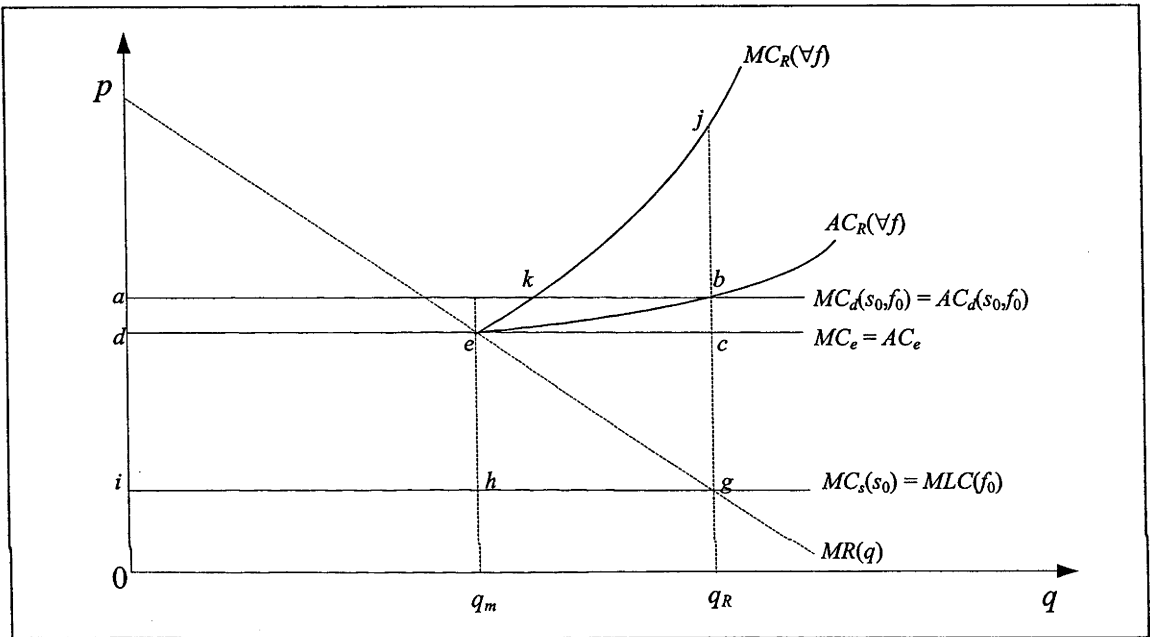
- is drawn for a given fair rate of return on capital;
- corresponds to points lying along the inefficient expansion path  $qep_d$ , which in the input-space diagram of Figure 3.3.1, diverges from the efficient expansion path  $qep_e$  over all the units of output produced; and
- leads to some portion of the increase in the social cost of production, being captured over all the units of output produced by the ROR-regulated monopoly (i.e. from 0 to  $q_R$  units of output).

In contrast, using the results established here and in Section 3.2, the Sheshinski social marginal cost curve:

- is drawn for all the possible values of the regulated fair rate of return  $f$ ;
- corresponds to the points lying along the AJ Path, which in the input-space diagram of Figure 3.3.1, only diverges from the efficient output expansion path  $qep_e$  for those units of output produced exceeding monopoly output  $q_m$ ;
- leads to the increase in the social cost of production only being captured over the additional units of output that ROR regulation induces the monopoly to produce (i.e. from  $q_m$  to  $q_R$  units of output.)

While the Carlton and Sheshinski social marginal cost curves have very different diagrammatic representations in the price-quantity space, due to the different expansion paths they correspond to in the input space, the analysis here shows that both yield identical outcomes in relation to the overall cost of production to society under ROR regulation. To link the two social marginal cost curves, it is useful to derive the social average cost curve that implicitly arises from the analysis of Sheshinski.<sup>21</sup> This is done with assistance of the price-quantity diagram in Figure 3.3.4.

**FIGURE 3.3.4 THE COST CURVES OF CARLTON AND SHESHINSKI**



To determine the shape of the Sheshinski social average cost curve under constant-returns-to-scale technology, it is necessary to find the points in the price-quantity space that the curve passes through. As the unregulated monopoly uses the efficient input mix to produce  $q_m$  units of output, the social average cost curve drawn for all levels of  $f$ —i.e.  $AC_R(\nabla f)$ —must initially be equal to the efficient average cost curve  $AC_e$ , and pass through point  $e$ . Assuming that the regulator sets the fair rate  $f_0$ , the total social cost of producing  $q_R$  units of output is  $C_d$ , which in Figure 3.3.4, is captured by area  $abq_R0$ . As this area is the same regardless of the social average cost curve used, it must be the case that the Sheshinski social average cost curve  $AC_R(\nabla f)$  passes through point  $b$ . By

<sup>21</sup> Sheshinski did not derive a social average cost curve. For an analysis that does contain diagrams showing both the average and marginal cost curves drawn for all levels of the fair rate of return, see Bailey (1973) at page 106.

mapping  $AC_R(\forall f)$  through points  $e$  and  $b$ , as shown in Figure 3.3.4, under constant-returns-to-scale technology the social average cost curve drawn for all levels of  $f$ , will be upward-sloping in the price-quantity space.

Once again, as the unregulated monopoly uses the efficient input mix, the Sheshinski social marginal cost curve  $MC_R(\forall f)$  must be equal to the efficient marginal cost curve  $MC_e$  at  $q_m$  units of output, and pass through point  $e$ . As the social average cost curve  $AC_R(\forall f)$  is increasing, it must also be the case that the Sheshinski social marginal cost curve  $MC_R(\forall f)$  drawn for all levels  $f$  is increasing and lies above  $AC_R(\forall f)$ . Therefore, using the Sheshinski social marginal cost curve  $MC_R(\forall f)$  in Figure 3.3.4, the total cost of producing the regulated level of output  $q_R$  associated with the fair rate of return  $f_0$ , will be captured by the area  $abq_R0$ .<sup>22</sup>

Given that the social marginal cost curve  $MC_R(\forall f)$  passes through point  $j$  in Figure 3.3.4, the combined areas  $deq_m0$  and  $ejq_Rq_m$  will be equal to area  $abq_R0$ , or alternatively area  $abcd$  must be equal to area  $ejc$ . This implies that for the level of output produced by the monopoly under any given fair rate  $f$ , the Carlton production-deadweight-loss banana must be equal to the area by which the Sheshinski marginal cost curve  $MC_R(\forall f)$  exceeds the efficient marginal cost curve  $MC_e$ . It follows from this that the different areas used by Sheshinski and Waterson to depict the overall welfare change resulting from ROR regulation will also be equal.

### 3.3.3 The Efficiency Trade-Off: A Bigger Banana for an Increase in Output

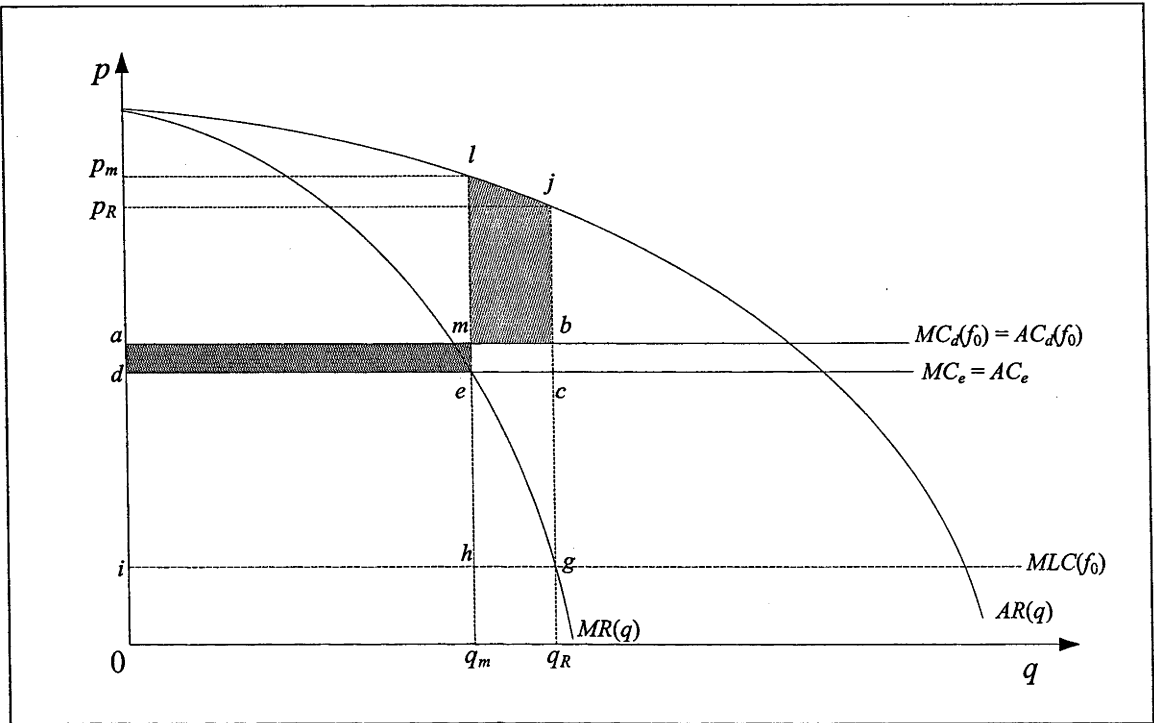
By incorporating a demand curve into the diagram of Figure 3.3.2, the price-quantity diagram used by Waterson to assess the impact of ROR regulation on the monopoly, is illustrated in Figure 3.3.5.<sup>23</sup> In this diagram, the increase in output from  $q_m$  to  $q_R$ , leads to an increase in allocative efficiency of area  $ljce$ , while the inefficient over-capitalisation in production (or AJ effect) results in a Carlton production-deadweight-loss “banana” equal to area  $abcd$ . Therefore, as in the analysis of Waterson, the overall

<sup>22</sup> This is consistent with the diagram of Bailey (1973), who shows (at page 106) that when the ROR-regulated monopoly is subject to constant-returns-to-scale production technology, the social and average marginal cost curve drawn for all levels  $f$  is upward-sloping.

<sup>23</sup> The price-quantity diagram used by Waterson (1989) does not incorporate a marginal labour cost curve. Waterson just specifies some level of output resulting from ROR regulation and unlike Figure 3.3.5, does make explicit why this level of output  $q_R$  is being produced.

increase in welfare that results from ROR regulation is now captured over two areas, and is equal to  $ljbm - amed$ .

FIGURE 3.3.5 WELFARE UNDER ROR REGULATION WITH CARLTON COST CURVES



In Chapter 2 it was established that there was a greater level of production inefficiency, the closer the fair rate  $f$  was set to the normal rate of return on capital  $r$ . In terms of the price-quantity diagram this means that, while a lower fair rate will lead to an increase in output and a greater level of allocative efficiency, this must be traded-off against a bigger production-deadweight-loss banana. It is possible to imagine that a situation could arise where a further reduction in the fair rate leads to a decrease in welfare, as the subsequent increase in the production-deadweight-loss banana exceeds any increase experienced in allocative efficiency. A welfare-maximising regulator will be interested in avoiding such an outcome, and will set the fair rate to maximise the difference between the production-deadweight-loss banana and the increase in allocative efficiency.

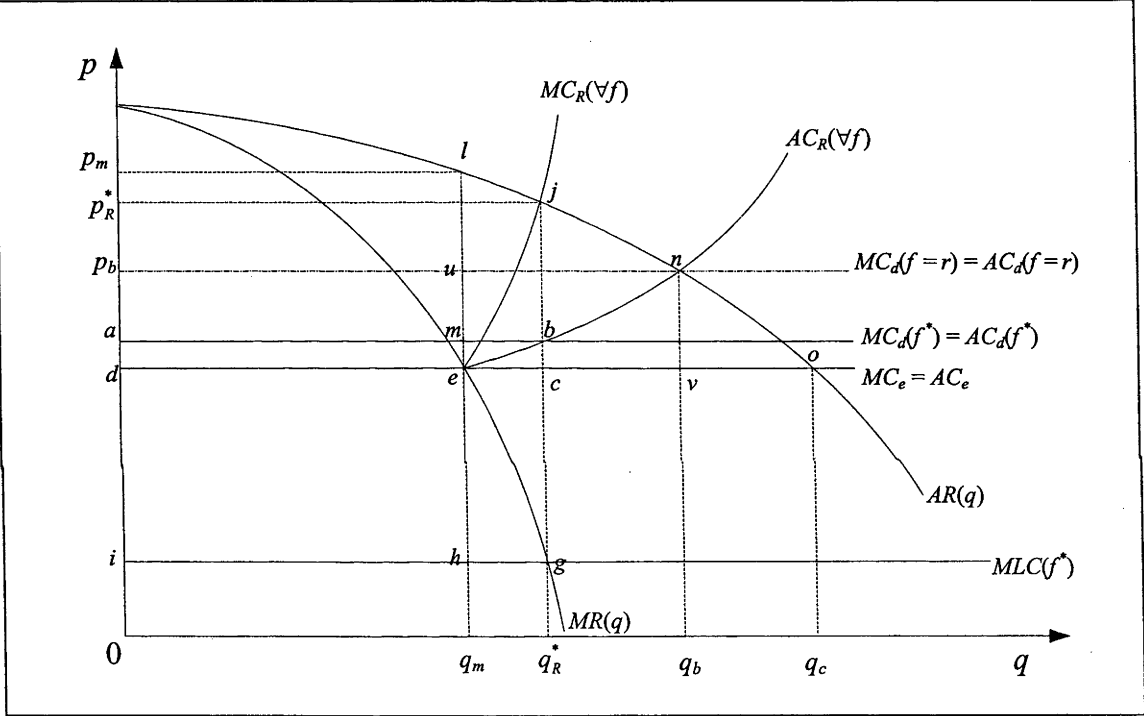
To maximise welfare under ROR regulation, the fair rate of return must be set at a level  $f^*$ , where the marginal production-deadweight-loss banana will be equal to the marginal gain in allocative efficiency from the additional units of output supplied. In order to:

- assist with illustrating the welfare-maximising outcome for the ROR-regulated monopoly;

- highlight the different areas used in the analysis of Sheshinski and Waterson to capture the change in welfare under ROR regulation; and
- show that under constant-returns-to-scale technology a fair rate  $f$  set within an infinitesimal amount of  $r$  will not be optimal;

the Sheshinski social marginal and average cost curves are added to the diagram in Figure 3.3.6. To avoid having to change the labels for such things as the production deadweight-loss banana, it is assumed here that the fair rate previously denoted  $f_0$  in Figure 3.3.5, is also the welfare-maximising fair rate  $f^*$ .

FIGURE 3.3.6 THE WELFARE-MAXIMISING FAIR RATE



In Figure 3.3.6, to maximise the total allowed return on capital at the welfare-maximising fair rate  $f^*$ , the monopoly produces the level of output  $q_R^*$ , where the marginal revenue of production  $MR(q)$  is equal to the marginal labour cost  $MLC(f^*)$ , and per-unit price charged is  $p_R^*$ . The welfare gain that results from setting the optimal fair rate can be illustrated using either the Sheshinski or Carlton social marginal cost curve. While the marginal cost curves capture the same increase in welfare, the areas used to depict this welfare gain differ. The Carlton social marginal cost curve, used in the analysis of Waterson, shows a welfare gain equal to  $ljb - amed$ , while the Sheshinski social marginal cost curve illustrates that there is a welfare gain of  $lje$ . Regardless of how the welfare gain from ROR regulation is measured, it is lower than



that experienced under the first-best outcome, where there is an increase in welfare of *loe*.

To establish why a fair rate set within an infinitesimal amount of  $r$  will not be optimal here, it is assumed that the ROR-regulated monopoly employs an input mix along the AJ path for any allowed fair rate  $f$  that is set greater than or equal to  $r$ .<sup>24</sup> In these circumstances, if  $f$  were set equal to  $r$ , the firm would earn zero economic profit and over-capitalise in producing the break-even level of output  $q_b$ . Although output  $q_b$  exceeds the level of output achieved under the optimal fair rate  $f^*$ , it leads to a lower level of welfare due to the substantial increase in production inefficiency. Using the Carlton social marginal cost curve, when  $f$  is set equal to  $r$ , the production-deadweight-loss banana will be equal to  $p_b nvd$ , and the overall welfare change is  $lnu - p_b ued$ . As it is possible for this welfare change to be negative, under constant-returns-to-scale technology, excessive ROR regulation of the monopoly can potentially induce worse outcomes than having an unregulated monopoly. Instances where there may be end-point solution for the optimal fair rate (i.e.  $f^* = r$ ), as opposed to the interior solution outlined so far (i.e.  $r_m > f^* > r$ ), are explored in Section 3.4.

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<sup>24</sup> See Bailey (1973) at pages 104-7.

### 3.4 The Optimal Fair Rate of Return

Sheshinski (1971) was the first to address the issue of the optimal fair rate of return, and derived an interior solution for the optimal fair rate  $f^*$  (i.e.  $r_m > f^* > r$ ). Shortly after, Klevorick (1971) considered the same issue. However, unlike Sheshinski, he recognised that there could either be an interior or end-point solution for the optimal fair rate (i.e.  $f^* > r$  or  $f^* = r$ ). A distinguishing feature of the work done by Klevorick (1971) was that he assumed the monopoly would employ an efficient input mix when the fair rate  $f$  was set equal to  $r$ . Bailey (1973) highlights the key results of the two papers at pages 104-7. Her analysis demonstrates that:

- if it is assumed the firm operates at a point along the AJ path for all values of the fair rate  $f$  greater than or equal to  $r$ , then:<sup>25</sup>
  - an interior solution is optimal (i.e.  $r_m > f^* > r$ ) if the average cost curve  $AC_R(\forall f)$  lies below the marginal cost curve  $MC_R(\forall f)$  at the end point on the AJ path;
  - an end-point solution is optimal (i.e.  $f^* = r$ ) if the average cost curve  $AC_R(\forall f)$  is equal to or exceeds the marginal cost  $MC_R(\forall f)$  at the end point on the AJ path.<sup>26</sup>
- if it is assumed the firm operates efficiently when the fair rate  $f$  is set equal to  $r$ , then where the ROR-regulated monopoly faces constant or decreasing costs of average, there will be an end-point solution for the optimal fair rate (i.e.  $f^* = r$ ). Otherwise, an interior solution exists for the optimal fair rate.<sup>27</sup>

This Section uses price-quantity diagrams similar to those employed by Bailey, to illustrate the outcomes for the optimal fair rate under different assumptions and cost conditions. While the exposition provided here is not original, and essentially

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<sup>25</sup> See Proposition 6.6 at page 104-5.

<sup>26</sup> It is important to note that although not mentioned by Bailey, there is a reason why she did not use the terminology increasing-returns-to-scale in her analysis. Although increasing returns implies an unregulated monopoly faces a decreasing average and marginal cost curve, for a ROR-regulated monopoly this is not necessarily the case. Under ROR regulation, because of the inefficient over-capitalisation in production, the marginal cost curve faced by the regulated monopoly  $MC_R(\forall f)$  diverges from the decreasing efficient marginal cost curve  $MC_e$ , and may be increasing over certain levels of production. Subsequently, under increasing returns it is possible that the average cost curve faced by the ROR-regulated monopoly  $AC_R(\forall f)$  could lie below  $MC_R(\forall f)$ , leading to an interior solution for the optimal fair rate.

<sup>27</sup> See Proposition 6.7 at page 107.

reproduces the work of Bailey, it is crucial for the analysis that is eventually done in Section 3.6. This assesses the results of Yang and Fox (1994), and examines the precise conditions where the introduction of a capital tax will increase and decrease welfare in the AJ framework.

This Section initially contrasts the solutions for the optimal fair rate obtained by Sheshinski and Klevorick, by examining an outcome where the ROR-regulated monopoly faces constant-returns-to-scale production technology. This example illustrates the discontinuous nature of the assumption made by Klevorick that the firm employs an efficient input mix when  $f$  is set equal to  $r$ . The Klevorick assumption is subsequently ignored, and an outcome is illustrated where there will be an end-point solution for the optimal fair rate, under the alternative assumption that the ROR-regulated firm operates at a point along the AJ path for all  $f$  greater than or equal to  $r$ .

#### 3.4.1 Contrasting the Sheshinski and Klevorick Optimal Fair Rates

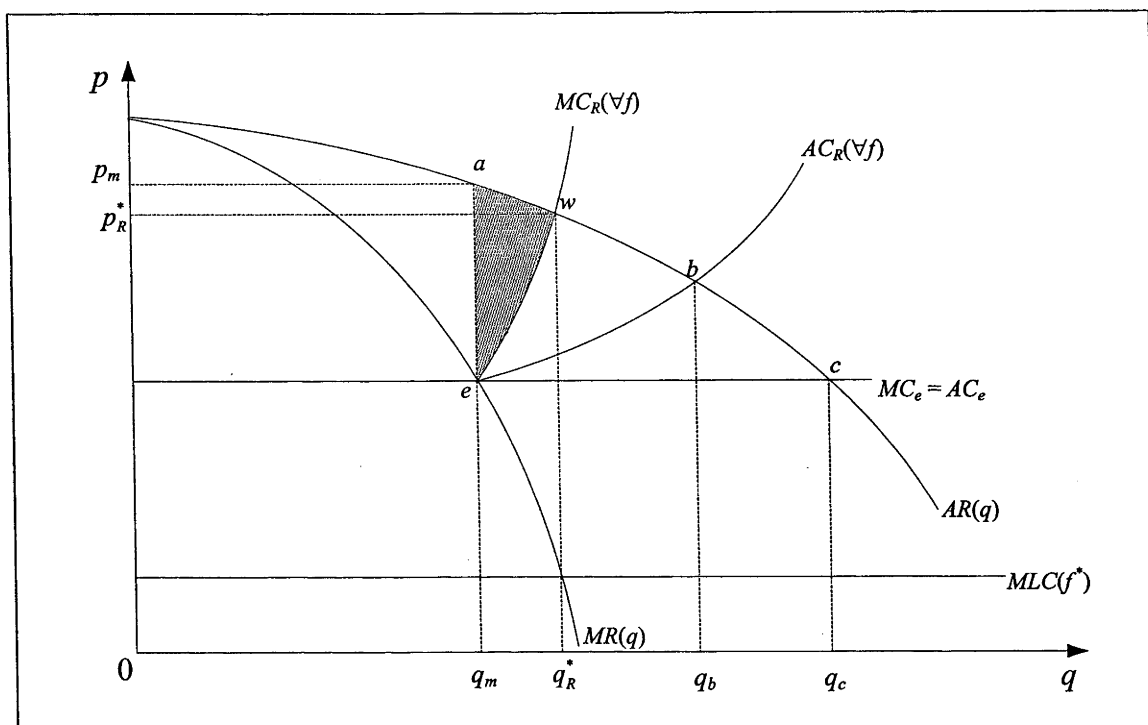
The price-quantity diagram in Figure 3.4.1 is similar to the diagram of Figure 6-9(a) at page 106 of Bailey (1973). As in Bailey it is assumed here that capital is a normal input,<sup>28</sup> and the diagram uses what was referred to in Section 3.3 as the Sheshinski average and social marginal cost curves — i.e.  $AC_R(\forall f)$  and  $MC_R(\forall f)$ . To illustrate the different optimal fair rates derived by Sheshinski (1971) and Klevorick (1971), an example is used where it is assumed the ROR-regulated monopoly faces constant-returns-to-scale technology in production.

The analysis in Section 3.3.3 has already shown that with constant returns, there will be an interior solution for the optimal fair rate  $f^*$  (i.e.  $r_m > f^* > r$ ) when it is assumed that the firm employs an input mix along the AJ path for any  $f$  set greater than or equal to  $r$ . In Figure 3.4.1, this leads to  $q_R^*$  units of output being produced and a welfare gain of area  $awe$ . In contrast, if it is assumed the firm employs an efficient input mix when  $f$  is set equal to  $r$ , there will be an end-point solution for the optimal fair rate  $f^*$  (i.e.  $f^* = r$ ). ROR regulation now induces a first-best outcome, as the regulated firm supplies the competitive level of output  $q_c$ , and there is a welfare gain of area  $ace$ .

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<sup>28</sup> As shown in the previous Sections, this assumption implies that the introduction of ROR regulation leads to an increase in output and welfare.

FIGURE 3.4.1 THE OPTIMAL FAIR RATE UNDER CONSTANT RETURNS



The outcome using the Klevorick approach highlights the arbitrary nature of the assumption he has made. In the AJ framework, as  $f$  is set closer to the normal rate of return  $r$ , the firm increases its inefficient over-capitalisation in production and increases output towards  $q_b$ . When the fair rate is within an infinitesimal amount of  $r$  (i.e.  $f = r + \varepsilon$ , where  $\varepsilon > 0$ ), the level of output will also be within an infinitesimal amount of  $q_b$  (i.e.  $q_b = q_b - \varepsilon$ ). However, under the assumptions of Klevorick, when there is now a very slight reduction in the fair rate to  $r$ , this results in a substantial change in the input mix employed by the producer, a relatively large increase in output from  $q_b - \varepsilon$  to  $q_c$ , and a large increase in the level of welfare.<sup>29</sup>

To avoid such a jump in the level of output and welfare for a very small change in the fair rate, the assumption of Klevorick is ignored throughout the remainder of the work done in this Section, and the course of the Chapter. To remove the problem of indeterminacy and having a discontinuous solution when  $f$  is set equal to  $r$ , it is instead assumed that the firm continues to over-capitalise in production and employs an input

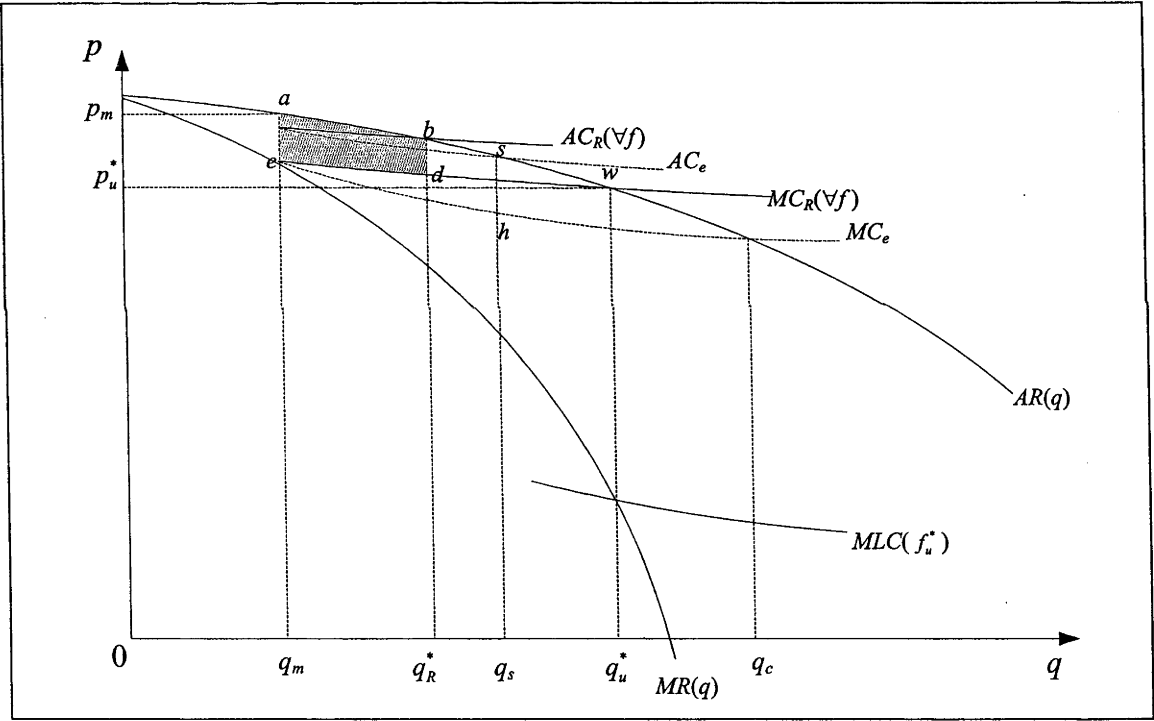
<sup>29</sup> As outlined in Section 3.3, where the fair rate is set equal to  $r + \varepsilon$ ,  $\varepsilon > 0$ , it is possible that there will be a welfare loss experienced from ROR regulation. In these circumstances, if the assumption of Klevorick were adopted, then a very small reduction in the fair rate of return to  $r$ , would lead to the overall welfare loss under ROR regulation being turned into an overall welfare gain.

mix lying on the AJ path for all  $f$  set greater than or equal to  $r$  (i.e.  $f \geq r$ ). This ensures the equivalence outcome with the capital subsidy is retained even when  $f$  is set equal to  $r$ . Further, it implies that in Figure 3.4.1, if the fair rate of return  $f$  were set equal to  $r$ , the firm produces the break-even level of output  $q_b$ , which is less than the competitive level of output  $q_c$ .

### 3.4.2 An End-Point Solution for the Optimal Fair Rate

To illustrate an instance where there is an end-point solution for the optimal fair rate, the price-quantity diagram in Figure 3.4.2 is used. This depicts a case where the ROR-regulated monopoly faces an average cost curve  $AC_R(\forall f)$  that lies above the marginal cost curve  $MC_R(\forall f)$ . It is similar to the diagram drawn by Bailey in Figure 6-9(b).

FIGURE 3.4.2 THE OPTIMAL FAIR RATE WITH A DECREASING AVERAGE COST



In Figure 3.4.2, if the regulator were to set the welfare-maximising fair rate without having any regard to firm profit, price  $p_u^*$  would be set, which is equal to the marginal cost of production faced by the ROR-regulated monopoly,  $MC_R(\forall f)$ . However, because this marginal cost curve  $MC_R(\forall f)$  lies below the average cost curve  $AC_R(\forall f)$ , such a price leads to a long-run loss. Consequently, the socially-optimal unconstrained fair

rate  $f_u^*$  that corresponds to price  $p_u^*$ , lies below the break-even or normal rate of return  $r$ .<sup>30</sup> To ensure that the welfare-maximising outcome is achieved, subject to the constraint that the regulated firm recovers its long-run costs, the regulator here must set the optimal fair rate  $f^*$  equal to  $r$  (i.e.  $f^* = r$ ).<sup>31</sup>

In Figure 3.4.2, when the fair rate  $f$  is set equal to  $r$ , the level of output  $q_R^*$  is supplied. This leads to an overall welfare gain from ROR regulation equal to area  $abde$ . Compared to the price  $p_u^*$  that arises from setting the socially-optimal unconstrained fair rate, there is an inefficiency of  $bwd$ . While setting the fair rate equal to  $r$  represents the best outcome for society under ROR regulation, given the constraint that the monopoly recovers its long run costs of production, it does not yield a Ramsey-Boiteux price. For such a second-best outcome, the level of output  $q_s$  must be supplied, which would lead to a welfare gain of area  $ashe$ . The reason ROR regulation is not second-best efficient is that the firm still over-capitalises in its production when  $f$  is set equal to  $r$ , and the average cost curve  $AC(\forall f)$  exceeds the efficient average cost of production  $AC_e$ . It seems more appropriate to describe the outcome achieved by the end-point solution here as being “third-best”. That is, it represents the best the regulator can do given that the monopoly is constrained to earning zero profit, and that ROR regulation induces the firm to inefficiently over-capitalise in its production.

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<sup>30</sup> Technically, the AJ path is not defined for any fair rate  $f$  less than  $r$ . Subsequently, to conceptualise the marginal cost curve and level of output associated with fair rate  $f_u^*$ , it is necessary to imagine that  $f_u^*$  corresponds to some optimal capital subsidy  $s^*$ . Unlike the regulated monopoly earning the fair rate  $f_u^*$ , the optimally-capital-subsidised monopoly continues its production, and employs an input mix lying on the AJ path. The outcome depicted in Figure 3.4.2, where the end-point solution for  $f^*$  no longer corresponds to the optimal capital subsidy  $s^*$ , is why only the interior solution of Sheshinski was considered in Section 3.2.

<sup>31</sup> Although not depicted in Figure 3.4.2, as outlined in the introduction of this Section, there will also be an end-point solution for the optimal fair rate when the marginal cost curve  $MC_R(\forall f)$  is equal to the average cost curve  $AC_R(\forall f)$  at the end point on the AJ path. In contrast to the outcome illustrated here, in such circumstances, the socially-optimal unconstrained fair rate  $f_u^*$  will be equal to the normal rate of return  $r$ , and also identical to the optimal fair rate  $f^*$ . The end-point solution would then lead to a distorted-marginal-cost-based price that would allow the firm to earn zero economic profit and recover its long-run costs of production.

### 3.5 The Optimal Fair Rate — A Worked Example

This Section examines the issue of the optimal fair rate and the equivalent optimal capital subsidy, by revisiting and building upon the alternative model of ROR regulation outlined in Section 2.6 of Chapter 2. To find the optimal fair rate, the additional assumption made here is that there is a perfectly-informed regulator who aims to maximise welfare. By using the same Cobb-Douglas production technology and linear demand as in Section 2.6, the welfare-maximising condition established in Section 3.2 is solved, and an analytical solution derived for both the optimal fair rate and the corresponding optimal capital subsidy. By also adopting the same parameter values as in Section 2.6, the outcomes for the unregulated and ROR-regulated monopoly subject to the optimal fair rate  $f^*$  are calculated, and then contrasted in a diagram. From this, the size of the production-deadweight-loss banana and welfare gain are found, and optimal ROR regulation is compared with a production subsidy when there is a positive marginal excess burden. The results once again highlight the equivalence between the capital-subsidised monopoly and the ROR-regulated monopoly in the AJ model.

#### 3.5.1 The Behaviour of a Perfectly-Informed-Welfare-Maximising Regulator

In Section 2.6 it was shown that an equivalent outcome to the AJ model could be generated, by having perfectly-informed shareholders instructing management of the ROR-regulated monopoly, to behave as if the firm were receiving a capital subsidy. From this, an expression was derived for the capital subsidy as a function of the fair rate. To find the welfare-maximising fair rate and corresponding optimal capital subsidy, the framework used in Section 2.6 is modified here, so that there is now:

- (i) a perfectly-informed-welfare-maximising regulator;
- (ii) perfectly-informed-total-dividend-maximising shareholders; and
- (iii) a manager that acts on the instructions of shareholders.

As the fair rate  $f$  is set closer to  $r$ , the regulator recognises that the shareholders will instruct the manager to behave as if it is receiving a higher capital subsidy. This means that, as in the AJ model, the benefit of increased production is partially offset by an increase in the level of inefficient over-capitalisation. Therefore, the welfare-maximising regulator will set a fair rate that induces shareholders to instruct management to behave as if they are receiving a capital subsidy, which equates the

marginal gain in allocative efficiency with the marginal loss in production efficiency. Such a fair rate can be found by using the equation for the optimal condition described in Section 3.2. Solving this, and denoting the welfare-maximising outcomes with superscript \*, the optimal fair rate of return set by the regulator is,

$$\begin{aligned} f &= f^*(w, r) \\ \text{s.t. } f^* &\geq r \end{aligned} \quad (3.5.1)$$

Substituting this expression into equation (2.6.9) implies that the corresponding optimal capital subsidy set by shareholders is,

$$s = s^*(w, r) \quad (3.5.2)$$

Further, substituting equation (3.5.1) into equations (2.6.10a) through to (2.6.10g), the following optimal identities are derived.

$$k_R = k_R^*(w, r) \quad (3.5.3a)$$

$$n_R = n_R^*(w, r) \quad (3.5.3b)$$

$$q_R = h(n_R^*, k_R^*) = q_R^*(w, r) \quad (3.5.3c)$$

$$p_R = p(h(n_R^*, k_R^*)) = p_R^*(w, r) \quad (3.5.3d)$$

$$\pi_s = \pi(n_R^*, k_R^*) = \pi_s^*(w, r) \quad (3.5.3e)$$

$$\pi_R = \pi_s(n_R^*, k_R^*) - sk_R^* = \pi_R^*(w, r) \quad (3.5.3f)$$

$$D_R = D(n_R^*, k_R^*) = D_R^*(w, r) \quad (3.5.3g)$$

### 3.5.2 The Maximisation Problem for the Regulator

The welfare-maximising regulator induces the shareholder to provide the socially-optimal capital subsidy by setting the appropriate fair rate. This fair rate is found by solving the welfare-maximising condition derived in Section 3.2 and outlined in equation (3.2.16). In the partial-equilibrium framework used here, this condition translates to the requirement that,

$$p_R(w, r, s) \frac{dq_R(w, r, s)}{ds} = \frac{dC(w, r, s)}{ds} \quad (3.5.4)$$

Substituting equations (2.6.20c) and (2.6.20d) into the above, with the linear demand and Cobb-Douglas technology of Section 2.6, the left-hand side of equation (3.5.4) is,



$$p_R(w, r, s) \frac{dq_R(w, r, s)}{ds} = \frac{1}{2b} \left( \frac{a}{2} + w^{1/2}(r-s)^{1/2} \right) \left( \frac{w}{r-s} \right)^{1/2} \quad (3.5.5a)$$

As  $C$  denotes the actual cost of production faced by the firm and society,

$$C(w, r, s) = wn_R(w, r, s) + rk_R(w, r, s)$$

Substituting in the expressions for  $n_R$  in equation (2.6.20a), and  $k_R$  in equation (2.6.20b), and simplifying, the total cost of production to society in the presence of a capital subsidy or ROR regulation is,

$$C = \frac{1}{b} \left( \frac{w}{r-s} \right)^{1/2} \left[ \frac{a}{2} - w^{1/2}(r-s)^{1/2} \right] (2r-s)$$

Therefore the right-hand side of the welfare-maximising condition given by equation (3.5.4) is

$$\frac{dC(w, r, s)}{ds} = \left( \frac{w}{r-s} \right)^{1/2} \left( \frac{as(r-s)^{1/2} + 4w^{1/2}(r-s)^2}{4b(r-s)^{3/2}} \right) \quad (3.5.5b)$$

Substituting equations (3.5.5a) and (3.5.5b) into (3.5.4), it is possible to solve for the welfare-maximising capital subsidy set by shareholders  $s^*$ ,<sup>32</sup>

$$s^*(w, r) = r - \left( \frac{a^2 r^2}{36w} \right)^{1/3} \quad (3.5.6)$$

Substituting equation (3.5.6) into (2.6.19) and simplifying, yields the expression for the optimal fair rate  $f^*$  that the perfectly-informed regulator should set.

$$f^*(w, r) = \left( \frac{a^4 r}{48w^2} \right)^{1/3} \quad (3.5.7)$$

To ensure that  $s$  is strictly positive, and  $f$  is greater than the normal rate of return  $r$ , a tighter restriction than  $a^2 > 4wr$  must be imposed upon the parameters of the model. That is, the parameters must satisfy the inequality,

$$36wr > a^2 > 4\sqrt{3}wr \quad (3.5.8)$$

Substituting equation (3.5.7) into (2.6.20a) through to (2.6.20h), the expressions for the welfare-maximising level of capital, labour, output, price, capital-subsidised monopoly

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<sup>32</sup> As the equation is highly non-linear, this solution was found with the assistance of Mathematica.

profit, ROR-regulated monopoly profit, total dividend payments, and the marginal cost of production used by managers, is as follows.

$$n_R = n_R^*(w, r) = \frac{1}{b} \left( \frac{ar}{6w^2} \right)^{\frac{1}{3}} \left[ \frac{a}{2} - \left( \frac{war}{6} \right)^{\frac{1}{3}} \right] \quad (3.5.9a)$$

$$k_R = k_R^*(w, r) = \frac{1}{b} \left( \frac{6w^2}{ar} \right)^{\frac{1}{3}} \left[ \frac{a}{2} - \left( \frac{war}{6} \right)^{\frac{1}{3}} \right] \quad (3.5.9b)$$

$$q_R = q_R^*(w, r) = \frac{1}{b} \left[ \frac{a}{2} - \left( \frac{war}{6} \right)^{\frac{1}{3}} \right] \quad (3.5.9c)$$

$$p_R = p_R^*(w, r) = \frac{a}{2} + \left( \frac{war}{6} \right)^{\frac{1}{3}} \quad (3.5.9d)$$

$$\pi_s = \pi_s^*(w, r) = \frac{1}{b} \left[ \frac{a}{2} - \left( \frac{war}{6} \right)^{\frac{1}{3}} \right]^2 \quad (3.5.9e)$$

$$\pi_R = \pi_R^*(w, r) = \frac{a}{2b} \left[ \frac{a}{2} - \left( \frac{war}{6} \right)^{\frac{1}{3}} \right] \left[ 1 - \left( \frac{48w^2r^2}{a^4} \right)^{\frac{1}{3}} \right] \quad (3.5.9f)$$

$$D_R = D_R^*(w, r) = \frac{a}{2b} \left[ \frac{a}{2} - \left( \frac{war}{6} \right)^{\frac{1}{3}} \right] \quad (3.5.9g)$$

$$MC_s(s^*) = MC_s^*(w, r) = 2 \left( \frac{arw}{6} \right)^{\frac{1}{3}} \quad (3.5.9h)$$

In addition, by substituting equation (3.5.7) into  $C$ , and dividing through by  $q_R^*$ , an expression is derived for the Carlton average and marginal cost of production to society  $MC_d$  at fair rate  $f^*$ . That is,

$$MC_d(f^*) = MC_d^*(w, r) = \left( \frac{6w^2r^2}{a} \right)^{\frac{1}{3}} + \left( \frac{awr}{6} \right)^{\frac{1}{3}} \quad (3.5.9i)$$

### 3.5.3 A Numerical Example

The numerical example provided here, is done purely for illustrative purposes. It serves to further highlight the link between the fair rate and equivalent capital subsidy, by showing that the results of the alternative model of ROR regulation used here, are consistent with the theoretical outcomes of the AJ model. The example is not designed

or purported to represent actual outcomes that might arise under ROR regulation, and for this reason only one numerical example is used. This is unlike the detailed pseudo-empirical analysis of Klevorick (1971) and Callen, Mathewson and Mohrig (1976), which derive numerical results for the AJ model using many different parameter values.

To find numerical outcomes for the optimal identities derived in this model of ROR regulation, the same parameter values are adopted as in Section 2.6. That is,  $a = 5$ ,  $r = 0.1$  and  $w = 15$ . Here, the additional assumption that must be made is that the slope of the linear demand curve  $b$  is equal to 0.001. Applying these values to the equations outlined here, and the unregulated monopoly outcomes in Section 2.6, yields the results outlined in the following table.

**TABLE 3.5.1 RESULTS FOR THE UNREGULATED AND ROR-REGULATED MONOPOLY**

Unregulated Monopoly		ROR-Regulated Monopoly	
$k_m$	15618.6	$k_R^*$	19811.9
$n_m$	104.1	$n_R^*$	102.2
$\alpha_e = k_m / n_m$	150.0	$\alpha_R^* = k_R^* / n_R^*$	193.9
$q_m$	1275.26	$q_R^*$	1422.78
$p_m$	3.73	$p_R^*$	3.58
$\pi_m$	1626.28	$\pi_s^*$	2024.31
		$\pi_R^*$	1575.77
$D_m$	3188.14	$D_R^*$	3556.96
$MC_e$	2.45	$MC_s(s^*)$	2.15
		$MC_d(f^*)$	2.47
$r_m$	0.2041	$f^*$	0.1795
		$s^*$	0.0226
$\varepsilon_m$	2.92	$\varepsilon_R^*$	2.51

From Table 3.5.1, it is clear that the numerical results derived for this alternative model of ROR regulation, are consistent with the theoretical results of the AJ model of ROR regulation. For instance:

- constant-returns-to-scale technology implies that both capital and labour are normal factors of production, and as Bailey (1973) showed, in the AJ model, this leads to the fair rate inducing an increase in the level of output that is supplied. Table 3.5.1, illustrates that this outcome also occurs here, as the level of production has increased from 1275 to 1423 units of output;
- Baumol and Klevorick (1970) show that with constant-returns-to-scale technology, the ROR-regulated monopoly has a higher capital-labour ratio than the unregulated monopoly. Table 3.5.1, illustrates this outcome holds in this model of ROR regulation, as the capital-labour ratio for the unregulated monopoly is  $\alpha_e = 150$ , while the capital-labour ratio for the ROR-regulated monopoly is  $\alpha_r^* = 193.9$ ;
- in Section 3.3 it was shown that the Carlton social marginal cost curve in the AJ Model of ROR regulation, was higher than the efficient marginal cost curve, due to inefficient over-capitalisation in production. This outcome is confirmed in Table 3.5.1. The marginal cost faced by society at the optimal fair rate  $f^*$  is  $MC_d(f^*) = 2.47$ , which exceeds the efficient marginal cost of production  $MC_e = 2.45$ . Subsequently, there is a Carlton production-deadweight-loss banana here;
- ROR regulation in the AJ model is also considered to be a constraint on the profits that the monopoly is allowed to earn. This is captured in Table 3.5.1 by the owners of the regulated monopoly, only receiving profit of  $\pi_r^* = 1575.77$ , while the owners of an unregulated monopoly receive profit of  $\pi_m = 1626.28$ .<sup>33</sup> The price that the ROR-regulated monopoly receives on each unit of output sold  $p_r^* = 3.58$ , is also less than the price the unregulated monopoly receives on each unit of output sold  $p_m = 3.73$ ;
- Section 3.4 demonstrated that with constant-returns-to-scale technology, when the firm is assumed to use an input mix on the AJ path for all  $f \geq r$ , the optimal fair rate of return  $f^*$  lies within the bounds  $r_m > f^* > r$ . The outcome derived here, is consistent with this result, as  $f^* = 0.1795$ , while  $r_m = 0.2041$  and  $r = 0.1$ .

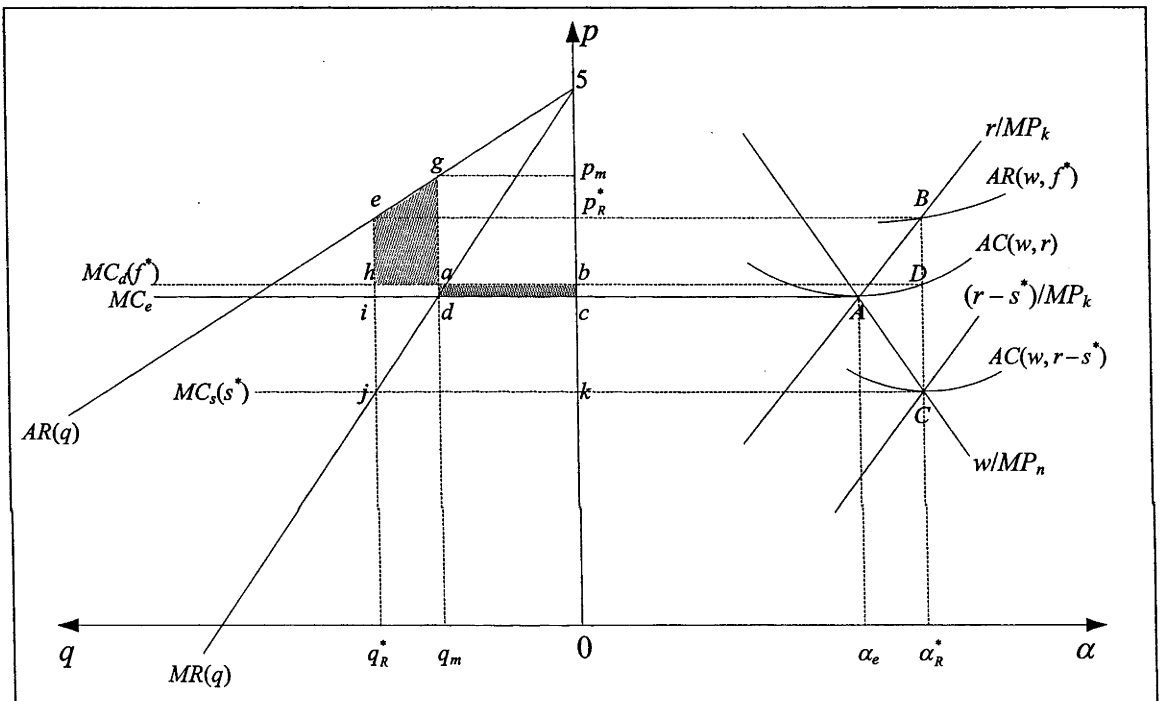
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<sup>33</sup> Although the table indicates total dividend payments have increased under ROR regulation, if it is assumed that each unit of capital is equal to a share in the firm, the dividend payment on each share (i.e. the rate of return) has decreased.

- Chapter 2 showed that in the AJ model, the ROR-regulated monopoly produces in the elastic portion of the demand curve. That is, the price elasticity of demand  $\varepsilon$ , is greater than 1. Table 3.5.1 indicates that such an outcome also arises here, as the price elasticity of demand under the optimal fair rate of return is  $\varepsilon_R^* = 2.51$ .

To assist with further discussion of the results in Table 3.5.1, and to illustrate the points and areas that the terms correspond to, the following price-quantity space diagram is provided in Figure 3.5.1.

**FIGURE 3.5.1 THE ROR-REGULATED MONOPOLY OUTCOME**



The right-hand-side (RHS) of the diagram in Figure 3.5.1 shows the average and marginal costs of production as a function of the capital-labour ratio  $\alpha$ , under constant-returns-to-scale production technology. The left-hand-side (LHS) of the diagram in Figure 3.5.1 shows the corresponding outcome in the price-quantity space.

Point A in the RHS of Figure 3.5.1 shows that the unregulated monopoly is efficient in its production, as it employs the efficient capital-labour ratio  $\alpha_e$ , which coincides with the minimum point on the social average and marginal cost curve  $AC(w, r)$ . In the price-quantity space on the LHS, this outcome corresponds to efficient marginal cost curve  $MC_e$ . As the firm continues to employ capital and labour and to produce output until  $MR$  equals  $MC_e$ , it leads to  $q_m$  units of output being supplied, an unregulated monopoly price of  $p_m$ , and a level of profit  $\pi_m$ , equal to area  $gp_mcd$ .

When the firm is subject to the welfare-maximising fair rate  $f^*$ , the shareholder instructs the manager to act as if it is receiving the optimal capital subsidy  $s^*$ . The RHS of Figure 3.5.1 illustrates that the overall result of this is that there is over-capitalisation in the production of output. As the manager behaves as if it is receiving the capital subsidy, they use the lower cost of capital  $r - s^*$ , and employ the capital-labour ratio  $\alpha_R^*$ , which is higher than the efficient capital-labour ratio  $\alpha_e$ . This outcome coincides with point  $C$ , the minimum point on the average private and marginal cost curve that the manager is using on the instruction of shareholders,  $AC(w, r - s^*)$ . In the LHS diagram, the private marginal cost of production used by the manager is depicted by the marginal cost curve  $MC_s(s^*)$ . It is the point where this curve intersects the marginal revenue curve  $MR(q)$ , that determines the level of output supplied by the regulated firm  $q_R^*$ . This leads to the price  $p_R^*$  being charged for each unit of output, and in the RHS of Figure 3.5.1, this coincides with point  $B$  on average revenue curve  $AR(w, f^*)$ . Based on this level of production, if the firm were actually subsidized, profit of  $\pi_s^*$  would be earned, which is equal to area  $ep_R^*kj$ .

The distorted input mix however, leads to the owners of the firm, and society, incurring a higher marginal cost of production. This is illustrated in the RHS of Figure 3.5.1. The firm and society face an average and marginal cost of production that coincides with point  $D$  on  $AC(w, r)$ . This lies above the minimum cost at point  $A$ . In the price-quantity space, the production inefficiency is captured by the Carlton social marginal cost curve  $MC_d(f^*)$ . Therefore, the level of profit that accrues to the owners of the firm is  $\pi_R^*$ , which is equal to area  $ep_R^*bh$ . Here, area  $hbkj$  is equal to the total amount of the capital subsidy  $s^*k_R^*$  that the management acts as if it is receiving under ROR regulation.

As in Section 3.3, the regulator must trade-off the gain in allocative efficiency from the additional units provided as a result of a decrease in the fair rate, with the increase in the production-deadweight-loss banana that results from the increased over-capitalisation in production. At the optimal fair rate  $f^* = 0.1795$ , and the corresponding optimal capital subsidy  $s^* = 0.0226$ , the production-deadweight-loss banana is equal to area  $hbci$ , while the gain in allocative efficiency is equal to area  $egdi$ . This yields an overall welfare gain represented by the shaded area  $egah - abcd$

Using the values from Table 3.5.1, numerical solutions can be obtained for the gain in allocative efficiency, the production deadweight loss (*DWL*), and the overall welfare change, that arises from the regulator setting the optimal fair rate  $f^*$  equal to 0.1795. That is,

$$\text{Allocative Efficiency Gain} = \frac{1}{2}(p_m - p_R^*)(q_R^* - q_m) + (p_R^* - MC_e)(q_R^* - q_m) = 177.76 \quad (3.5.10)$$

$$\text{Carlton Production-DWL "Banana"} = (MC_d(f^*) - MC_e)q_R^* = 28.46 \quad (3.5.11)$$

Subtracting the production inefficiency from the gain in allocative efficiency yields,

$$\Delta \text{ Welfare} = 149.30 \quad (3.5.12)$$

Therefore, the optimal fair rate  $f^*$  results in an overall welfare gain of \$149.30.

Using these calculations it is also possible to compare ROR regulation with a production subsidy when there is some positive marginal excess burden. As outlined in equation (2.5.6) in Section 2.5, where the marginal excess burden is denoted by  $\omega$ , for ROR regulation to be superior to a production subsidy that induces the same level of production  $q_R^*$ , the following relationship must be satisfied.

$$\omega > \frac{C_d - C_e}{C_e - C_s} = \frac{\text{Production-DWL Banana}}{\text{Production Subsidy Payment}} \quad (3.5.13)$$

Based on estimates of  $\omega$  in Australia by Campbell and Bond (1997), ROR regulation will be superior to a production subsidy in this example, if the value of the right-hand-side of equation (3.5.13) is less than approximately 0.24. As the value production-deadweight-loss banana has already been found, an estimate is required for the amount of the production subsidy payment that must be made to induce the monopoly to produce output  $q_R^*$ .

$$\text{Total Production Subsidy Payment} = (MC_s(s^*) - MC_e)q_R^* = 426.83 \quad (3.5.14)$$

This implies that the value of the RHS of equation (3.5.13) is,

$$\frac{C_d - C_e}{C_e - C_s} = \frac{28.46}{426.83} = 0.067 \quad (3.5.15)$$

The above result suggests that in this numerical example, the optimal fair rate is less costly for society to use than a production subsidy that induces the same level of output.

### 3.6 The Impact of a Capital Tax on Welfare in the AJ Model

Yang and Fox (YF, 1994) show that it is possible to increase welfare by levying a capital tax (or what they refer to as “property tax”) on the ROR-regulated monopoly. This Section initially summarises the main results established by YF. Using the analysis and diagrams done in Section 3.4, it then establishes when the introduction of a capital tax will increase and decrease welfare. It is illustrated here that a capital tax **decreases** welfare if there is:

- an interior solution for the optimal fair rate (i.e.  $r_m > f^* > r$ ), and the regulator initially sets the fair rate  $f$  above the optimal fair rate  $f^*$  (i.e.  $r_m > f > f^* > r$ ); or
- an end-point solution for the optimal fair rate (i.e.  $f^* = r$ ).

Based on these results it is necessary to clarify and restate some of the findings and conclusions originally made by YF about the properties of the welfare-improving capital tax.

#### 3.6.1 The Main Results of Yang and Fox (1994)

In the YF variation on the AJ model, the ROR-regulated monopoly maximises the after-tax profits of the firm subject to the regulatory constraint. That is, where  $t$  denotes the tax rate on the value of the capital equipment, the regulated firm

$$\begin{aligned} \max_{n,k} \pi &= p(h(n,k))h(n,k) - wn - (r+t)k \\ \text{s. t. } \frac{p(h(n,k))h(n,k) - wn}{k} &= f \quad \text{and} \quad f > r \end{aligned} \tag{3.6.1}^{34}$$

YF employ the same mathematical techniques as Baumol and Klevorick (1970) to solve the model, and present the results in a series of seven propositions. For the purposes of the analysis here the important results are summarised by the following three points:

- (i) a change in the capital tax  $t$  has exactly the same effect on labour, capital and output as a change in the regulated fair rate of return  $f$ ;
- (ii) the introduction of a capital tax, or an increase in an existing capital tax, can improve welfare. YF recognise that this result arises due to the tax offsetting the

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<sup>34</sup> This is not quite the same maximisation done by YF. They also assume there is some positive price paid for each unit of physical capital acquired  $c$ . For simplicity, as in the AJ model, it is assumed here this per-unit acquisition cost  $c = 1$ .



inefficient over-capitalisation from the AJ effect. They contend that this means the property tax can be categorised as a “Pigouvian tax” on capital. Further, they state (at page 59) that it yields an interesting theoretical result, because it “contradicts the long-established belief that a lower (or no) tax is preferred to a higher tax in maximising welfare”;<sup>35</sup> and

- (iii) a change in the capital tax has the same overall impact on welfare as a change in the fair rate. YF point out that this result has an interesting policy implication. It means that if the regulator misses the optimal fair rate by some amount  $\Theta$ , then the tax authority can intervene and maximise welfare by adjusting their tax rate by the amount  $-\Theta$ . However, they also suggest (at page 66) that the different objectives of the relevant authorities, means that “this offsetting policy is likely to be only a theoretical possibility”.

The first result has already been addressed in Chapter 2. There it was outlined that the equivalent impact of the capital tax could be attributed to the ROR-regulated monopoly subject to a lower fair rate, behaving as if it were receiving a higher capital subsidy. While the result suggests YF may have understood that the ROR-regulated monopoly behaves as if it is receiving a capital subsidy, from a detailed assessment of their statements and conclusions in Section 3.6.5, it is apparent that they did not appreciate this insight.

YF identify the potential for the capital tax to improve welfare, by initially finding conditions where the same increase in the tax rate and fair rate, leads to an increase in tax revenue that exceeds the increase in profit. By then assuming that there is a linear demand curve and an explicit social welfare function  $W$  — comprised of consumer surplus, profit and the total tax revenue from the capital tax  $t$ , i.e.  $W = CS + \pi + T$  — YF show that:

- it is possible for  $\partial W/\partial t$  to be greater than 0, and
- $\partial W/\partial t$  is equal to  $\partial W/\partial f$ .

To assess the second and the third results in greater detail, it is necessary to investigate the precise circumstance when a capital tax leads to a welfare gain and loss. A thorough critique of the results is left for the final part of the Section.

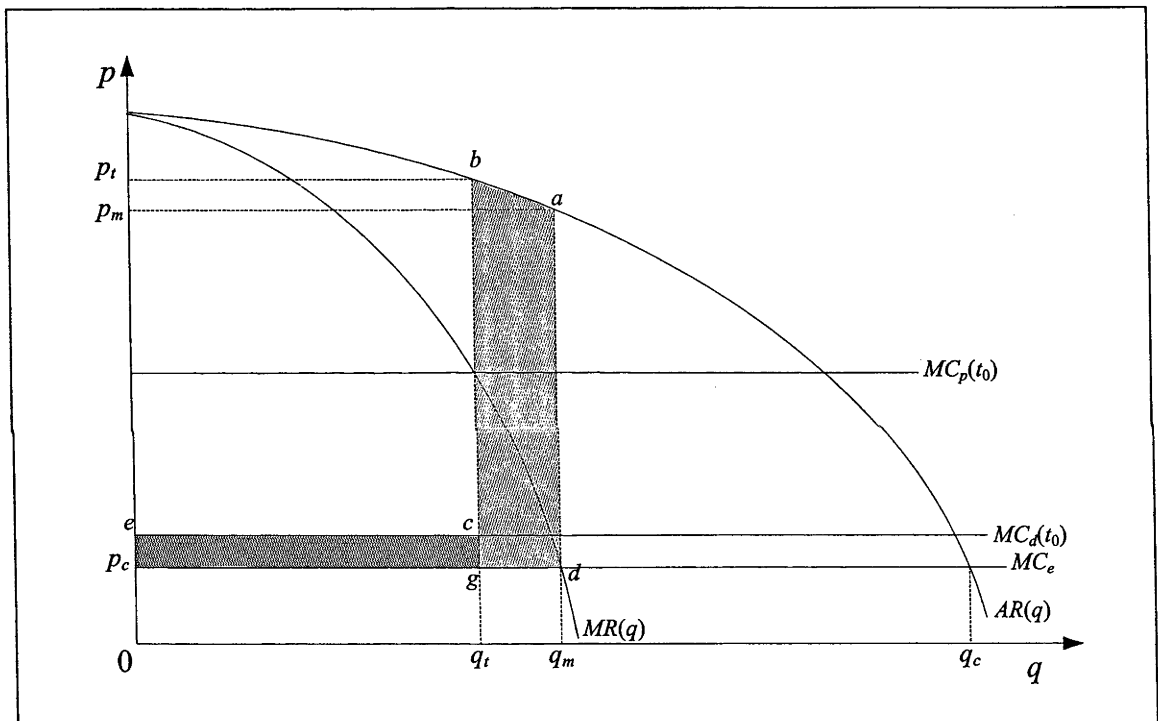
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<sup>35</sup> A similar statement is made by YF at page 65.

### 3.6.2 The Impact of a Capital Tax on the Unregulated and Regulated Monopoly

To understand the impact of levying a capital tax on the ROR-regulated monopoly, it is instructive to first analyse the impact such a tax has on the unregulated monopoly. As the capital tax is effectively a negative capital subsidy, the results of Section 2.3 apply here in reverse. That is, the monopoly subject to the capital tax  $t$  under-capitalises in production, and as it assumed throughout that capital is a normal input, it leads to a lower level of output being produced. Using the Carlton marginal cost curves from Section 3.3, the increased cost to society and the decreased level of output produced by the unregulated monopoly is captured in Figure 3.6.1.

**FIGURE 3.6.1 THE IMPACT OF A CAPITAL TAX ON THE UNREGULATED MONOPOLY**



In terms of the welfare change, the reduction in the quantity of output supplied from  $q_m$  to  $q_t$  decreases allocative efficiency by  $badg$ , while the under-capitalisation in the production of output  $q_t$ , leads to a production-deadweight-loss banana equal to area  $ecgp_c$ . Consequently, for the unregulated monopoly, the capital tax results in an unambiguous welfare loss of area  $badg + ecgp_c$ .

In contrast, when a capital tax is placed on the ROR-regulated monopoly, it will reduce the level of output and allocative efficiency, but increase the level of production efficiency. This is achieved by partially offsetting the over-capitalisation that originally arises from the AJ effect. Whether the capital tax increases overall welfare though, depends upon whether the marginal benefit derived from the increase in production

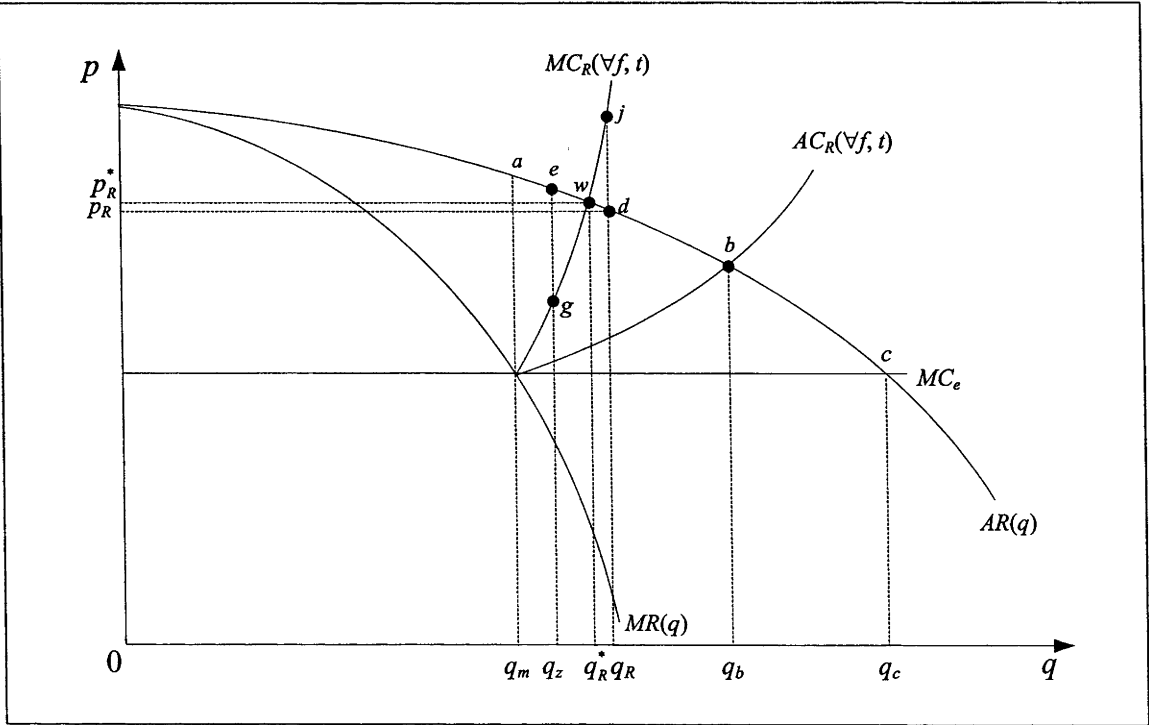
efficiency, is greater than the marginal cost created by the decrease in allocative efficiency. In turn, this depends upon the combination of:

- (1) the level of the fair rate set by the regulator; and
- (2) the marginal and average cost curves faced by the ROR-regulated monopoly.

### 3.6.3 Where the Introduction of a Capital Tax Increases Welfare

It is assumed here that the firm operates at a point along the AJ path for all values of the fair rate  $f$  greater than or equal to  $r$ . Consequently, it follows from the analysis done by Bailey (1973), and outlined in Section 3.4, that if  $AC_R(\forall f)$  lies below  $MC_R(\forall f)$  at the end point on the AJ path, there will be an interior solution for the optimal fair rate  $f^*$  (i.e.  $r_m > f^* > r$ ). In these circumstances, if the regulator sets the fair rate of return  $f$  above the optimal fair rate  $f^*$ , so that  $f^* > f > r$ , then even though the firm earns greater than zero profits, from society's perspective the fair rate is being set too low — i.e. there is excessive ROR regulation. In terms of efficiency, constraining the monopoly to earning such a fair rate is equivalent to providing the monopoly with an excessive capital subsidy (i.e.  $s > s^*$ ). It will therefore be possible to increase welfare by imposing the appropriate capital tax. Figure 3.6.2 provides an illustration of an instance where the introduction of a capital tax on the ROR-regulated monopoly can increase welfare. In this diagram, as in Figure 3.4.1, it is assumed the firm faces constant-returns-to-scale production technology.

FIGURE 3.6.2 THE CAPITAL TAX WITH AN INTERIOR SOLUTION FOR THE FAIR RATE



In Figure 3.6.2 the marginal and average social cost of production are depicted by the curves  $MC_R(\forall f, t)$  and  $AC_R(\forall f, t)$ . These curves are similar to the Sheshinski marginal and average cost curves used in Section 3.3, which were drawn for all possible values of the fair rate  $f$  (i.e.  $\forall f$ ). The only difference here is that the marginal and average cost curves are not only drawn for all values of the fair rate  $f$ , but also for all values of the capital tax  $t$ . Therefore, like the Sheshinski cost curves, these curves correspond to points in the input space lying along the AJ path, which is now defined over all possible combinations of the fair rate and capital tax (i.e.  $AJP(\forall f, t)$ ).

To analyse Figure 3.6.2, it is assumed that there is initially no capital tax in place, and that the regulator sets a fair rate of return  $f_R$ , where  $f^* > f_R > r$ . At the resulting level of output  $q_R$  and the per-unit price  $p_R$ , the firm earns positive economic profit, and the marginal cost of production to society  $jq_R$  exceeds the marginal benefit to consumers  $dq_R$ . Compared to the outcome under the optimal fair rate  $f^*$ , there is an overall inefficiency of area  $wjd$ . The introduction of a small capital tax here, transfers some of the economic rents of the regulated monopoly to the government, and increases welfare. This occurs because the marginal gain from the decreased over-capitalisation in production exceeds the marginal cost of the decreased level of output supplied.

Assuming the regulated firm has sufficient revenue, it will be possible to induce further gains in welfare by increasing the capital tax rate until level  $t_R$  is reached. This is where the marginal benefit is equal to the marginal cost of imposing the tax, and based on the results of YF, this tax  $t_R$  will be equal to  $f^*$  minus  $f_R$  (i.e.  $t_R = f^* - f_R$ ). Distributional outcomes aside, the combination of the capital tax  $t_R$  and fair rate  $f_R$ , will be equivalent to the regulator originally setting the optimal fair rate  $f^*$ . Hence, the introduction of the capital tax  $t_R$  yields the socially-optimal level of output under ROR regulation  $q_R^*$ , and increases welfare by the amount  $wjd$ .<sup>36</sup>

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<sup>36</sup> It is apparent that there will also be some levels of the capital tax above  $t_R$ , which lead to a decrease in welfare. For example, a capital tax  $t_z > t_R$ , which in Figure 3.6.2 leads to  $q_z$  units of output being produced, decreases welfare if area  $ewg$  exceeds area  $wjd$ . In this situation it would have been better for society if the tax authority had not intervened, and the ROR-regulated monopoly had remained subject to the inefficient fair rate  $f_R$ .

### 3.6.4 Where the Introduction of a Capital Tax Decreases Welfare

#### 3.6.4.1 An Interior Solution for the Optimal Fair Rate

From the analysis done in the previous sub-section it follows that; where there is an interior solution for the optimal fair rate and the regulator initially sets the fair rate  $f$  above the optimal fair rate  $f^*$ , so that  $r_m > f > f^* > r$ , the introduction of a capital tax leads to an unambiguous welfare loss. Figure 3.6.2 can once again be used to illustrate this outcome.

If it is assumed that the regulator initially sets a fair rate of  $f_z$ , where  $r_m > f_z > f^*$ , in Figure 3.6.2, the ROR-regulated monopoly produces the level of output  $q_z$ . At  $q_z$ , the marginal benefit  $eq_z$  is greater than the marginal cost of production  $gq_z$ . Compared to the optimal fair rate  $f^*$  there is now an inefficiency equal to area  $ewg$ . Therefore, the marginal cost from levying any capital tax will exceed the marginal benefit that is derived from the reduced level of over-capitalisation in production. In other words, the effect the capital tax has on decreasing activity in the industry is so overwhelming that it exceeds any gain in production efficiency, and induces an overall welfare loss. For welfare to increase here, the firm would instead need to be provided with a capital subsidy. The issue of providing a subsidy to the regulated firm is looked at in greater detail in the following sub-section, which examines the case where there is an end-point solution for the optimal fair rate.

#### 3.6.4.2 An End-Point Solution for the Optimal Fair Rate

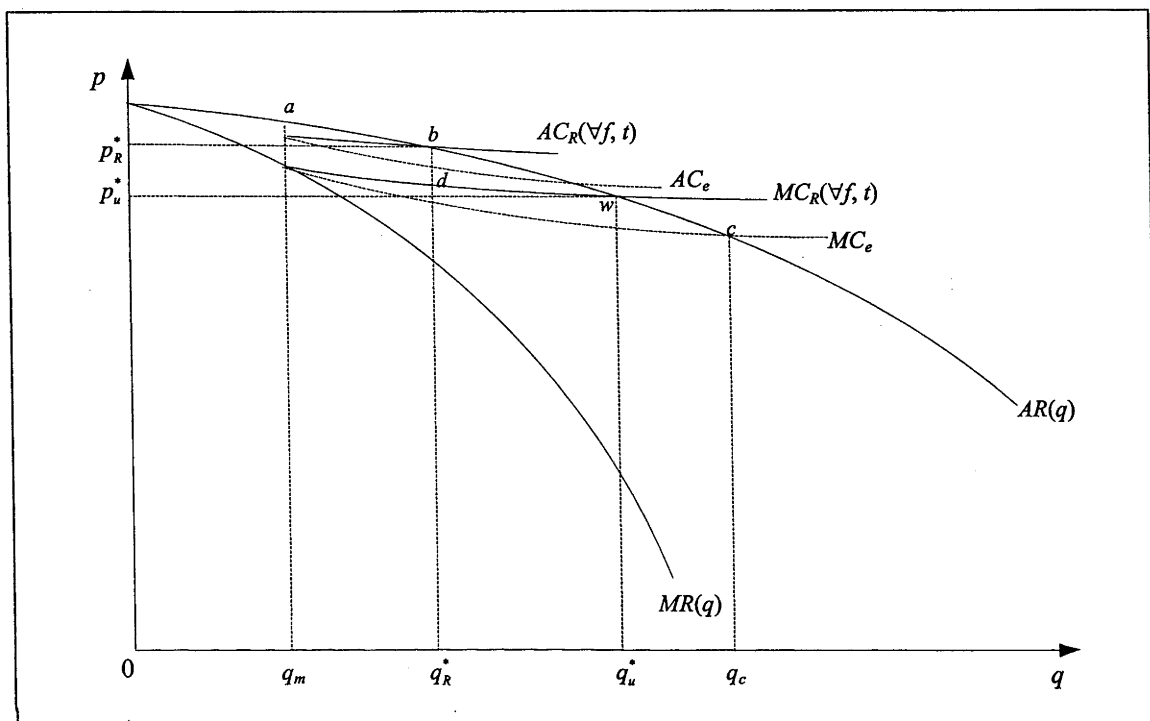
If  $AC_R(\forall f)$  is greater than or equal to  $MC_R(\forall f)$  at the end point of the AJ path, then as highlighted by Bailey (1973), and outlined in Section 3.4, there will be an end-point solution for  $f^*$  (i.e.  $f^* = r$ ). In this instance, if the regulator sets the fair rate  $f$  below the optimal fair rate  $f^*$ , the firm will choose to leave the industry as it makes long-run losses, and the capital tax cannot be introduced. If instead the regulator sets  $f$  above the optimal fair rate  $f^*$ , such that  $r_m > f > r$ , then as was the case for the interior solution, the introduction of a capital tax leads to an unambiguous welfare loss. In terms of efficiency, introducing a capital tax where the fair rate has initially been set too high, is equivalent to allowing the regulator to further increase the allowed fair rate above  $f^*$ .<sup>37</sup>

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<sup>37</sup> It follows trivially that for either an interior or end-point solution for  $f^*$ , where the regulator accurately targets the optimal fair rate, the imposition of a capital tax decreases welfare.

To highlight the problems associated with imposing a capital tax when there is an end-point solution for  $f^*$ , the diagram in Figure 3.6.3 is used. As in Section 3.4.2, it is assumed here that the average cost curve faced by the ROR-regulated monopoly lies above the marginal cost curve.

**FIGURE 3.6.3 THE CAPITAL TAX WITH DECREASING COSTS**



Section 3.4.2 established that although the end-point solution maximises welfare subject to the constraint that the ROR-regulated monopoly must recover its costs, because it is higher than the unconstrained socially-optimal fair rate  $f_u^* < r$ , it leads to output being under-supplied by the amount  $(q_u^* - q_R^*)$ , and an inefficiency of area  $bwd$ . To improve welfare in these circumstances, the ROR-regulated monopoly must be provided with an incentive to increase its production. As the introduction of a capital tax here decreases output, it leads to an unambiguous welfare loss. To induce the ROR-regulated firm to increase production, one solution is to provide it with a capital subsidy.

It is unlikely that the tax authority will have the jurisdiction to provide the ROR-regulated firm with a capital subsidy. Consequently, some other government department that deals with industry assistance will need to intervene — e.g. in Australia, the Department of Industry, Tourism and Resources. If the appropriate capital subsidy is provided, then combined with  $f^*$ , it will be equivalent to setting the unconstrained socially-optimal fair rate  $f_u^*$ , with the added benefit that the ROR-regulated firm now

recovers its long-run cost of production. Although the capital subsidy increases the level of over-capitalisation in production by the ROR-regulated monopoly, this inefficiency is outweighed by the efficiency gain from the additional units of output it supplies. The level of output  $q_u^*$  is produced, and assuming there is no marginal excess burden associated with the subsidy payment, there is an overall welfare gain equal to area  $bwd$ .

A government department could achieve a higher level of welfare under the cost conditions outlined in Figure 3.6.3, if instead of providing a capital subsidy, it granted the ROR-regulated firm a production subsidy that induced exactly the increase in output from  $q_R^*$  to  $q_u^*$ . Assuming there is a zero marginal excess burden associated with the production subsidy payment to the regulated monopoly, the welfare gain resulting from the production subsidy would exceed area  $bwd$ . The reason for this is that there is the same increase in output, but unlike the capital subsidy, there is now no corresponding increase in the level of inefficient over-capitalisation.

### 3.6.5 Revising and Clarifying the Capital Tax Results

YF provide a neat and mathematically rigorous exposition that highlights the impact of a capital tax on the ROR-regulated monopoly. They correctly identify that the introduction of a capital tax can improve welfare, and rely upon arguments about the relative changes that occur in the level of tax revenue and monopoly profit. Unlike the analysis done here though, they do not appear to appreciate the significance that the solution for the optimal fair rate has on whether the introduction of a capital tax will improve welfare.

The analysis here highlights that for introduction of the capital tax to increase welfare, two things are required:

- **there must be an interior solution for the optimal fair rate** (i.e.  $r_m > f^* > r$ ). As Bailey outlines, such an outcome occurs if the marginal cost curve faced by the ROR-regulated monopoly  $MC_R(\forall f)$  exceeds the average cost curve  $AC_R(\forall f)$  at the end point on the AJ path; and
- **the regulator must initially have set the fair rate of return  $f$  below the optimal fair rate  $f^*$  — i.e.  $f^* > f > r$ .**

Alternatively, it can be stated that the introduction of a capital tax decreases welfare if there is either:

- an interior solution for the optimal fair rate and  $f$  is set so that  $f > f^* \geq r$ ; or
- an end-point solution for the optimal fair rate (i.e.  $f^* = r$ ).

To increase welfare in these situations, rather than imposing a capital tax, it may be more appropriate to provide the ROR-regulated monopoly with a capital subsidy.

Aside from reassessing the results of YF, in light of the analysis done in this Section, a number of statements and claims made by YF about the properties of the welfare-improving capital tax should be clarified.

#### 3.6.5.1 *Introducing a Capital Tax when the Fair Rate is Too High*

In the final sentence of footnote 1 at page 60, YF thank “an anonymous referee for pointing out that the property tax will not be beneficial unless the allowed rate of return is inefficiently large.” The analysis done in this Section though illustrates that this statement is incorrect. The introduction of a capital tax will only ever increase welfare if there is an interior solution for the optimal fair rate, and the regulator has initially set the fair rate  $f$  below the welfare-maximising fair rate  $f^*$ . That is, compared to  $f^*$ , the regulator has set a fair rate  $f$  that is inefficiently low, i.e.  $f^* > f$ .

#### 3.6.5.2 *The Capital Tax Offsetting Inefficient Over-Capitalisation*

YF clearly understand that the capital tax they propose reverses the inefficient over-capitalisation created by the AJ effect. Their statement (at page 65) though that, “the property tax mitigates the overcapitalisation induced by the A-J effect”, appears slightly ambiguous. It may lead some readers to believe that the capital tax increases welfare, because it completely offsets the inefficient over-capitalisation arising under ROR regulation. However, such a tax will never be optimal, as in terms of the level of output and welfare, it leads to the unregulated monopoly outcome. Consequently, to avoid any potential for ambiguity, it would have been better if the authors had stated that the optimal capital tax *partially mitigates* the inefficient over-capitalisation originally induced by the AJ effect.

#### 3.6.5.3 *The Capital Tax — A Pigouvian Tax?*

The capital tax used in the YF model is referred to as being an example of a Pigouvian tax on capital. This is an inappropriate description for the capital tax that is imposed. A Pigouvian tax generally refers to a tax that increases welfare, by completely offsetting the inefficiency created by a negative externality. However, it is probably also



acceptable to describe it as a tax that leads to a welfare improvement, by completely removing an existing distortion in the market. The capital tax fails to satisfy either of these definitions of a Pigouvian tax.<sup>38</sup>

As the ROR-regulated monopoly clearly internalises the cost of the inefficient over-capitalisation, the capital tax does not offset the effects of any negative externality. Further, in all circumstances where the capital tax does increase welfare, it only partially mitigates the existing input distortion that arises from the AJ effect. Finally, while the capital tax does always decrease the existing input distortion, as outlined in this Section, it only results in an increase in welfare under certain conditions.

#### 3.6.5.4 *Do the Results Contradict Long-Established Beliefs about Taxation?*

YF maintain that the welfare-improving capital tax “contradicts the long-established belief that a lower (or no) tax is preferred to a higher tax rate in maximising welfare”. This assertion however appears to be over-stating the importance of the capital tax. It is well known that if a good is inefficiently subsidised, a tax can be used to remove this inefficiency. As constraining the ROR-regulated monopoly to earning too low a fair rate of return (i.e.  $f^* > f > r$ ) is equivalent to providing the firm with an excessive capital subsidy (i.e.  $s > s^*$ ), it follows that the introduction of a capital tax can improve welfare, and that this does not contradict any well-established beliefs.

It should also be noted here that when there is an interior solution for  $f^*$ , and the fair rate  $f$  has been set so that  $f^* > f > r$ , the capital tax that subsequently maximises welfare, can be described as an example of a second-best efficient tax. That is, it maximises welfare given the existing production efficiency distortion that arises from ROR regulation. Such a capital tax results in price being set equal to the distorted marginal cost  $MC_R$ , as opposed to the efficient marginal cost  $MC_e$ .

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<sup>38</sup> YF like many authors use the spelling Pigovian tax. While this spelling appears to be widely accepted by many academic journals and economists, particularly in the US, strictly speaking the correct spelling is Pigouvian tax. The reason is that only this spelling gives the appropriate recognition to the original exponent of this tax, the eminent economist A.C. Pigou.

### 3.7 Conclusion

The analysis in this Chapter examined the issue of welfare in the AJ model of ROR regulation. The work focused upon the allocative and production efficiency trade-off associated with the optimal fair rate  $f^*$ , and by using the equivalence result from Chapter 2, was able to build upon existing welfare results in the literature.

In Section 3.2, the equivalence result from Chapter 2 was used to establish a two-sector-two-period-single-person-general-equilibrium (GE) model of ROR regulation. By doing this the partial-equilibrium welfare results of Sheshinski were examined. It was shown that the interior solution for the optimal fair rate prescribed by Sheshinski only maximises welfare in general equilibrium if there are either, no cross-price effects or no efficiency distortions in the related market. As there does appear to be some substitutability in products provided across certain utility industries, and it is often necessary to allow price to be set above marginal cost to recover shared and common costs; the GE model appears to provide a useful insight into the adjustment required to the optimal fair rate of Sheshinski when there are related markets and irremovable efficiency distortions. The impact of ROR regulation on the monopoly, where there is an existing distortion in a related market, does not appear to have been considered in the previous GE analysis of ROR regulation.

Section 3.3 employed the methodology of Carlton (1979) to reconcile the alternative techniques used by Sheshinski (1971) and Waterson (1989), for depicting the impact of ROR regulation in the price-quantity space. It was shown that unlike the analysis of Sheshinski, which used a social marginal cost defined over all levels of the fair rate, Waterson implicitly used a “Carlton” social marginal cost curve, which was only drawn for a given fair rate of return. While the two marginal cost curves captured the same overall increase in the cost to society, and subsequently the same increase in welfare, they led to very different areas being used to depict these changes in the price-quantity space. Further, from applying the diagrammatic approach of Carlton, it was found that the production inefficiency arising from the AJ effect could be captured in the price-quantity space by a Carlton production-deadweight-loss “banana”. Consequently, the optimal fair rate  $f^*$ , can be characterised as requiring that the marginal increase in the production-deadweight-loss banana, be equal to the marginal gain in allocative efficiency.

In Section 3.5 the alternative model of ROR regulation established in Section 2.6, was modified to solve for an optimal fair rate and the corresponding optimal capital subsidy. By using the same parameter values and assumptions about production technology and demand as in Section 2.6, numerical results were derived. From this, the ROR-regulated monopoly outcome was compared with:

- an unregulated monopoly outcome; and
- a production-subsidised monopoly. It was assumed the production subsidy induced the monopoly to produce the same level of output as the ROR-regulated firm, and that there was a positive marginal excess burden associated with the subsidy payment.

The numerical results for the alternative model were shown to be consistent with the theoretical results of the AJ model, reinforcing the equivalence result established between the ROR-regulated and capital-subsidised monopoly.

Section 3.6 used the analysis and price-quantity diagrams outlined in Section 3.4, to assess the results of Yang and Fox (1994). This showed that although the introduction of a capital tax may improve welfare in the AJ model, this only occurs if:

- there is an interior solution for the optimal fair rate (i.e.  $r_m > f^* > r$ ); **and**
- the regulator initially sets the fair rate  $f$  below the optimal fair rate  $f^*$  (i.e.  $f^* > f > r$ ).

Conversely, the capital tax unambiguously decreases welfare if there is either:

- an interior solution for the optimal fair rate **and** the regulator sets  $f$  so that  $f > f^* \geq r$ ;  
**or**
- an end-point solution for the optimal fair rate (i.e.  $f^* = r$ ).

From the analysis, a number of the statements and conclusions made by Yang and Fox about the properties of welfare-improving capital tax were also assessed, and shown to be slightly ambiguous and misleading.

Although this concludes the analysis of the AJ model of ROR regulation, the impact that the regulated fair rate has upon investment and the overall level of efficiency, remains a common theme of the work that is done throughout the remaining Chapters.

## A.3 Chapter 3 Appendix

### A.3.1 Deriving the Welfare Equation in (3.2.7)

The steps used by Sieper (1981) and outlined by Jones (2001, 2003), are employed here to derive the welfare equation in (3.2.7). The methodology involves:

- totally differentiating the constrained maximisation problem faced by the consumer;
- applying the FOCs for the firm; and
- using the expression for the change in the lump-sum payment that is required to balance the government budget.

#### A.3.1.1 The Consumer Maximisation

Taking the total differential of the utility function for the consumer in equation (3.2.1),

$$dU = \frac{\partial U}{\partial x_0} dx_0 + \frac{\partial U}{\partial h} dh + \frac{\partial U}{\partial x_1} dx_1 + \frac{\partial U}{\partial x_2} dx_2 \quad (\text{A3.1.1})$$

To find each of the partial derivative terms (i.e.  $\partial U/\partial x_i$ ,  $i = 0, 1, 2$ ), the following Lagrangian is set up using the maximisation problem set out in equation (3.2.3)

$$\zeta = U(x_0, h, x_1, x_2) - \lambda \left( x_0 + z_1 x_1 + z_2 x_2 - \bar{x}_0 - \frac{w(T-h)}{1+r} - \pi_1 - \pi_2 - L \right) \quad (\text{A3.1.2})$$

Taking the FOCs with respect to  $x_0$ ,  $h$ ,  $x_1$  and  $x_2$ , and solving, yields

$$\frac{\partial U}{\partial x_0} = \lambda \quad (\text{A3.1.3a})$$

$$\frac{\partial U}{\partial h} = \frac{\lambda w}{1+r} \quad (\text{A3.1.3b})$$

$$\frac{\partial U}{\partial x_i} = \lambda z_i, i = 1, 2 \quad (\text{A3.1.3c})$$

Substituting equations (A3.1.3a), (A3.1.3b) and (A3.1.3c) into equation (A3.1.1), and simplifying yields,

$$\frac{dU}{\lambda} = dx_0 + z_1 dx_1 + z_2 dx_2 + \frac{w}{1+r} dh \quad (\text{A3.1.4})$$

As the Lagrange multiplier  $\lambda$  is the marginal utility of income to the consumer, the expression in equation (A3.1.4), represents the dollar change in utility that is experienced by a consumer as a result of any change in government policy.

Assuming the government does not change the production tax (i.e.  $dt_1 = dt_2 = 0$ ), the expression for the total differential of the budget constraint in equation (3.2.2) is,

$$\begin{aligned} dx_0 + z_1 dx_1 + z_2 dx_2 + \frac{x_1}{1+r} dp_1 - \frac{(p_1 + t_1)x_1}{(1+r)^2} dr - \frac{(p_2 + t_2)x_2}{(1+r)^2} dr \\ = -\frac{w}{1+r} dh + \frac{(T-h)}{1+r} dw - \frac{w(T-h)}{(1+r)^2} dr + d\pi_1 + d\pi_2 + dL \end{aligned} \quad (\text{A3.1.5})$$

Using this, equation (A3.1.4) can be rewritten as,

$$\begin{aligned} \frac{dU}{\lambda} = -\frac{x_1}{1+r} dp_1 + \frac{(p_1 + t_1)x_1}{(1+r)^2} dr + \frac{(p_2 + t_2)x_2}{(1+r)^2} dr \\ + \frac{(T-h)}{1+r} dw - \frac{w(T-h)}{(1+r)^2} dr + d\pi_1 + d\pi_2 + dL \end{aligned} \quad (\text{A3.1.6})$$

This can be further simplified by finding the expression for the change in profit for firms 1 and 2 (i.e.  $d\pi_1$  and  $d\pi_2$ ).

#### A.3.1.2 Maximisation Problem for the Monopolist and Competitive Industry

Taking the total differential of the profit functions in the two markets gives,

$$d\pi_1 = \frac{p_1}{1+r} dq_1 + \frac{q_1}{1+r} dp_1 - \frac{p_1 q_1 - wn_1}{(1+r)^2} dr - \frac{w}{1+r} dn_1 - \frac{n_1}{1+r} dw - (1-s)dk_1 + k_1 ds \quad (\text{A3.1.7})$$

$$d\pi_2 = \frac{p_2}{1+r} dq_2 - \frac{p_2 q_2 - wn_2}{(1+r)^2} dr - \frac{w}{1+r} dn_2 - \frac{n_2}{1+r} dw - dk_2 \quad (\text{A3.1.8})$$

As the FOCs for the capital-subsidised monopoly and the competitive market are,

$$\frac{p_1}{1+r} dq_1 + \frac{q_1}{1+r} dp_1 - \frac{w}{1+r} dn_1 - (1-s)dk_1 = 0 \quad (\text{A3.1.9})$$

$$\frac{p_2}{1+r} dq_2 - \frac{w}{1+r} dn_2 - dk_2 = 0 \quad (\text{A3.1.10})$$

it follows that (A3.2.9) and (A3.2.10) simplify to the expressions,

$$d\pi_1 = -\frac{p_1 q_1 - wn_1}{(1+r)^2} dr - \frac{n_1}{1+r} dw + k_1 ds \quad (\text{A3.1.11})$$

$$d\pi_2 = -\frac{p_2 q_2 - wn_2}{(1+r)^2} dr - \frac{n_2}{1+r} dw \quad (\text{A3.1.12})$$

Substituting equation (A3.1.11) and (A3.1.12) into the expression for the dollar change in utility given by equation (A3.1.4), and using the market clearing conditions for the labour market (i.e.  $T = h + n_1 + n_2$ ) and the goods market (i.e.  $x_1 = q_1$  and  $x_2 = q_2$ ), yields

$$\frac{dU}{\lambda} = -\frac{q_1}{1+r} dp_1 + \frac{t_1 q_1}{(1+r)^2} dr + \frac{t_2 q_2}{(1+r)^2} dr + k_1 ds + dL \quad (\text{A3.1.13})$$

### A.3.1.3 The Change in the Government Budget

Taking the total differential of the expression for the government budget in equation (3.2.6), and using the assumption that production taxes remain unchanged (i.e.  $dt_1 = dt_2 = 0$ ), yields

$$dG = \frac{t_1}{1+r} dq_1 + \frac{t_2}{1+r} dq_2 - \frac{t_1 q_1}{(1+r)^2} dr - \frac{t_2 q_2}{(1+r)^2} dr - s dk_1 - k_1 ds - dL \quad (\text{A3.1.14})$$

Setting equation (A3.1.14) equal to zero, the expression for the change in the lump-sum transfers that balance the government budget is,

$$dL = \frac{t_1}{1+r} dq_1 + \frac{t_2}{1+r} dq_2 - \frac{t_1 q_1}{(1+r)^2} dr - \frac{t_2 q_2}{(1+r)^2} dr - s dk_1 - k_1 ds \quad (\text{A3.1.15})$$

Therefore, in accordance with the conventional Harberger (1971) analysis, by substituting the equation (A3.1.15) into equation (A3.1.13), it is possible to evaluate the welfare effects of the lump-sum transfer used by the government to balance the budget. The resulting expression for the dollar change in utility simplifies to the **conventional welfare equation**,

$$\frac{dU}{\lambda} = -\frac{q_1}{1+r} dp_1 - s dk_1 + \frac{t_1}{1+r} dq_1 + \frac{t_2}{1+r} dq_2 \quad (\text{A3.1.16})$$

As the consumer is not compensated for the change in government policy that occurs here, (i.e.  $dL$  has **not** been set so that the government ensures the consumer achieves their initial level of utility and  $dU = 0$ ), the expression in equation (A3.1.16) captures the **uncompensated welfare change**, as opposed to the compensated welfare change.

Assuming there is no production tax on the output supplied by the ROR-regulated or capital-subsidised monopoly, (i.e.  $t_1 = 0$ ), the expression in equation (A3.1.16) can be further simplified for the outcome in equation (3.2.7).

$$\boxed{\frac{dU}{\lambda} = -\frac{q_1}{1+r} dp_1 - s dk_1 + \frac{t_2}{1+r} dq_2}$$

## **CHAPTER 4: FORWARD-LOOKING COST-BASED**

### **ACCESS PRICES IN US AND AUSTRALIAN TELECOMMUNICATIONS**

#### **4.1 Introduction**

Over recent years regulators across a range of countries have sought to introduce competition in previously state- or privately-owned monopolised gas, electricity, telecommunications and rail services. Due to persisting economies of scale and scope and the significant sunk costs associated with reconstructing certain portions of the network, regulators have sought to introduce competition by setting regulated terms on which entrants can access parts of an incumbent's network. In telecommunications, Noam (2002) states (at page 387) that the regulation of wholesale interconnection has:

...emerged as the paramount tool of regulation and is likely to remain so into the reasonably foreseeable future, replacing the regulation of telecommunications retail pricing of network operators, or of the entry of competitors.

A "fair" access price balances the need to create competition in downstream markets, while still ensuring the incumbent is adequately compensated for use of its asset.

In designing access regimes, concerns were raised over the use of the actual backward-looking (BL)/historical/embedded cost to value the asset. Noam defines BL or historic costs (at page 408) as being, "the actual cost incurred to build the network." While regulators traditionally employed BL costs to value the capital assets of the firm, due to the ease with which this data could be obtained, there was a growing recognition of the weaknesses associated with using such costs. In particular, concerns were raised that BL or historic costs:

- **reflected accounting rather than economic costs.** Hence, BL cost-based prices are unlikely to reflect the true opportunity costs to society of the resources being used, and do not provide the correct market signals about the value of additional production and investment; and
- **created incentives for cost inefficiency, such as capital waste and cost padding.** It did this by linking the access price directly to the costs originally incurred by the

firm. Laffont and Tirole (2000) outline (at page 144) that BL-fully-distributed-cost-based prices are cumbersome, fail to encourage cost-minimisation, and yield improper and inefficient pricing structures.<sup>1</sup>

The inadequacies of BL cost regulation has led to a recent trend amongst regulators to adopt a forward-looking (FL)/replacement cost standard. Noam notes (at page 408) in telecommunications that

...future *forward looking* cost methodologies do not involve the use of an embedded rate base, but rather postulates a hypothetical network based on near-term best-practice technology and efficient engineering.

In telecommunications, FL cost estimates of the long-run incremental cost have become “the dominant paradigm worldwide”,<sup>2</sup> and variations of the methodology are employed in the US, UK, Australia, New Zealand, Japan and Europe, to price access to network services. By approximating the long-run marginal cost of production, the access prices are designed to mimic the outcome in a competitive access market. This in theory will create incentives for efficiency, while still providing the investor with recovery on all prudently-incurred costs — including a fair rate of return on capital. However, since its inception, the FL cost-based access prices have been the subject of controversy. Industry commentators and prominent academics have criticised the charges, accusing it of being a cost calculation that systematically under-prices access to elements or services.

This Chapter provides an overview of the experiences in the US and Australian telecommunications industry with FL cost-based access regimes. It specifically looks at the introduction of the FL cost-based method known as:

- the total element long-run incremental cost (TELRIC), which has been used in the US by the Federal Communications Commission (FCC) to regulate the price for accessing the network of the incumbent local-exchange carriers (ILECs); and
- the total service long-run incremental cost (TSLRIC), which has been used in Australia by the Australian Competition and Consumer Commission (ACCC), to

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<sup>1</sup> Kahn, Tardiff and Weisman (1999), highlight (at page 325, footnote 11) that the use of historical accounting costs by the FCC before 1990, led to prices in an increasing number of companies being “simply frozen”.

<sup>2</sup> Productivity Commission (PC, 2001a) at page 407.



regulate the price for access to the Public Switched Telephone Network (PSTN) of the vertically-integrated service provider, Telstra.

The analysis outlines the major criticisms of TELRIC and TSLRIC, and assesses these in light of recent trends in both the US local and Australian PSTN services markets.

The Chapter is structured as follows. Section 4.2 provides a brief history of the US and Australian telecommunications markets, highlighting how the FL cost-based access regimes have emerged. Section 4.3 outlines some of the theory and practice underlying the calculation of the TELRIC and TSLRIC access charges, and outlines an explanation given by Pelcovits (1999) about the origins of the engineering-cost models used to calculate prices. Criticisms of the access regime in Australia and the US are outlined in Section 4.4, noting that similar arguments have been raised in both countries opposing the use of TELRIC or TSLRIC. Section 4.5 assesses the criticisms, and highlights limitations of certain arguments that been raised. Section 4.6 presents empirical evidence of trends in the US local telecommunications industry and the Australian PSTN services, since the introduction of TELRIC and TSLRIC. From this it appears that claims made about the adverse impact of FL cost regulation have been over-stated. Section 4.7 concludes the analysis.

## 4.2 An Overview of US and Australian Telecommunications

This Section provides a brief history of the telecommunications markets in the US and Australia. It outlines the early periods where there were monopoly providers in the US and Australia, and the substantial changes in the two markets in the latter half of the twentieth century. The analysis of the recent reforms examines how the current regulatory framework for network access has evolved in each country. In particular, it illustrates that the Federal Commerce Commission (FCC) and the Australian Competition and Consumer Commission (ACCC) have both adopted FL cost-based charges, designed to approximate long-run marginal cost, in pricing access to the network.

### 4.2.1 A Brief History of US Telecommunications

The analysis of telecommunications regulation in the US here is divided into three periods:

- the period before 1984, where a privately-owned monopoly served the majority of the US market;
- the period between 1984-1996, where the private monopoly was forced to separate structurally; and
- the period after the 1996 Telecommunications Act.

#### 4.2.1.1 *The Market before 1984*

Unlike many developed nations that provided telecommunications services using state-owned monopolies, the US adopted a regime where from the early part of the twentieth century, a well-established-privately-owned-vertically- and horizontally-integrated monopolist, AT&T (the Bell System), provided the majority of the services throughout the country, subject to regulation. At a Federal level, the Interstate Commerce Commission was initially responsible for the regulation of telecommunications. This role was eventually transferred to a new body created by the Communications Act of 1934, the Federal Communications Commission (FCC).

Brock (2002) outlines that in its operations throughout the 1940s and 1950s, the FCC significantly restricted entry to the telecommunications industry and there was no formal regulation of telephone rates of AT&T until the mid 1960s. According to Brock (at page 53), the “early FCC was an ideal regulatory agency from AT&T’s perspective”,

and he concluded (at page 54) that its regulations, “allowed AT&T to utilise the regulatory process to enhance its market power”.

The assistance the FCC provided to AT&T’s domination of the US telecommunications market meant that it remained relatively unchallenged for a period of more than fifty years.<sup>3</sup> Amongst other things, AT&T offered long-distance services, owned the equipment manufacturer Western Electric, the research and development arm Bell Laboratories, and the seven Local Bell Operating Companies — the “Baby Bells” — now referred to as Regional Bell Operating Companies (RBOCs).

Rapid technological progress in the industry meant that by the mid 1970s, doubts had begun to emerge over whether certain services should still be provided by only one firm. Combined with the Department of Justice’s belief that AT&T was abusing its market power, an investigation was launched into its failure to comply with antitrust laws. The litigation was settled in 1982, resulting in what has become known as the Modified Final Judgement (MFJ).

#### *4.2.1.2 The Market from 1984 to 1996*

The MFJ led to the break-up of AT&T in 1984. It represented a significant restructuring of the telecommunications industry, separating the market into legally-defined segments. AT&T retained its long-distance service, manufacturing subsidiary and R&D facilities, but was forced to divest itself of the seven RBOCs.<sup>4</sup> To achieve divestiture, the MFJ divided the parts of the country served by the Bells into 162 local access and transport areas (LATAs).<sup>5</sup> These geographical boundaries defined the regions within which each of the local exchange carriers (LECs) could operate. LECs were allowed to carry calls that originated and terminated within the same region

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<sup>3</sup> The first real challenge to AT&T’s market dominance was the entry of Microwave Communications Inc (MCI) into the long-distance market in the mid 1960s and early 1970s.

<sup>4</sup> After a series of mergers, four of the seven original RBOCs now remain. These are Verizon Communications Inc., BellSouth Corp., SBC Communications Inc., and Qwest Communications International Inc.

<sup>5</sup> This figure is from Woroch (2002) at page 653. He also points out that the number of LATAs has since grown to 193, as non-RBOC areas have been added. Curiously, Harris and Kraft (1997), Kahn, Weisman and Tardiff (Kahn et al., 1999) and Laffont and Tirole (2000) provide slightly different figures. According to Harris and Kraft (at page 96) and Kahn et al. (at page 320, footnote 2), divestiture was accomplished by creating 161 LATAs. According to Laffont and Tirole (at page 19), the MFJ divided those parts of the country served by the Bell system into 192 LATAs. Regardless of the actual number, it is clear that the total provided by Laffont and Tirole is incorrect, as they are obviously including non-RBOC areas into their final figure.

(IntraLATA services), but were prevented from offering the long-distances services that went across these boundaries (InterLATA services).

An almost immediate result of the separation was that, post-divestiture, there was an increased level of competition in the long-distance market. Concerns though were still raised over the monopoly power of local-exchange carriers — the “bottleneck” or essential component of the network — and there were ongoing complaints by the RBOCs about the line-of-business restrictions imposed. Consequently, in February 1996 Congress signed the Telecommunications Act of 1996 into law. This constituted the first comprehensive telecommunications legislation since the Communications Act of 1934. More significantly, according to Brock (at page 71), the Act “was a direct repudiation of the MFJ itself, and of the theory behind the MFJ” as it “assumed that competition was possible in all parts of the market.”

#### *4.2.1.3 The US Telecommunications Act 1996*

The intention of the Telecommunications Act was to reform the telecommunications industry by opening it up to competition. It envisaged what has been described as a “competitive free-for-all” in the provision of services,<sup>6</sup> where the market promoted the innovation and the level of investment necessary to modernise telecommunications infrastructure. The Act lifted the line-of-business restrictions that had previously kept the RBOCs out of the long-distance market, and in return required these incumbent local exchange carriers (ILECs) to open up their markets to competition.

The Telecommunications Act contemplated and purported to promote local-exchange competition through:

- **facilities-based competition;**
- **resale of the ILECs’ retail services; and**
- **unbundling network elements of the ILECs.**

**Facilities-based competition** occurs if a competing firm in the local telecommunications market builds its own local-exchange network. As the competing local-exchange carrier (CLEC) still requires interconnection to the ILECs’ networks, the Act prescribed that this should be done in a non-discriminatory manner and at a cost-based price.

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<sup>6</sup> Kahn, Weisman and Tardiff (Kahn et al., 1999) at page 320, and Weisman (2000) at page 196.

Laffont and Tirole (2000) maintain that, although Congress did not explicitly express any preference for the way in which local exchange competition should evolve, they appeared to favour facilities-based entry.<sup>7</sup> The FCC Chairman Michael Powell has also been a strong advocate of facilities-based entry by CLECs. He has indicated that the lease of network elements was designed to be a temporary measure to assist CLECs, while these firms constructed their own facilities. According to Chairman Powell, facilities-based competition represents the only viable long-term model for sustaining CLECs and competition in the local telecommunications market.<sup>8</sup>

**Resale** by the competitors of an incumbent's retail services is, according to Laffont and Tirole (at page 23), "generally considered to be an easy way of creating 'entry'" in a monopolised market where there are large sunk costs. In the case of the local telecommunications market the Act outlined that a CLEC could obtain an ILEC's retail services at a discounted wholesale access rate equal to retail price of the service minus the avoided costs of retailing the service — generally made up of marketing and billing costs that the ILEC no longer incurred.<sup>9</sup> The methodology represents a "top-down" cost model of pricing, as it sets the access price by subtracting the incremental costs associated with avoiding the retail market from the price of supplying the service.

Entry to the local telecommunications market by leasing the **unbundled network elements (UNEs)** of the incumbent — sometimes referred to as the unbundled network element platform (UNE-P) — has been described as a hybrid of facilities-based and resale entry.<sup>10</sup> Under this form of interconnection to the local network, the entrant provides some of its own equipment (e.g. switches) and leases other facilities from the incumbent (e.g. local loop or transport), so that it can ultimately supply a competing service in a downstream market.

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<sup>7</sup> Laffont and Tirole (2000) at page 22.

<sup>8</sup> For example see the articles, "Powell says States won't be stripped of UNE Power" appearing in the *Local Competition Report*, 27 January 2003, and "FCC's Powell Plans to Meet Deadline on New Phone Policy" by Mark Wigfield appearing on the *Dow Jones News Service*, 29 January 2003.

<sup>9</sup> Laffont and Tirole (2000) claim that this method of pricing is just an application of the efficient component-pricing rule (ECPR). However, this overlooks the well-established controversy surrounding the practical application of the ECPR, which was highlighted by Tye (1994). This ultimately led to its rejection by legislators in several countries including the US, New Zealand, UK and Australia. The ECPR is briefly dealt with in Section 4.5.4.

<sup>10</sup> Laffont and Tirole (2000) at page 24.

The Telecommunications Act prescribed minimum points of interconnection and provided a list of UNEs that the ILEC had to make available for competitors at a cost-based price. Originally the list consisted of seven elements, but over time the FCC has made numerous revisions. This has been due to advances in technology, the new preferences of consumers, and the increasing number of entrants choosing to supply or build their own facilities. An example of a change to the list was the FCC's decision in 1999 to unbundle the high-frequency range of the copper loop so that it could be made available to competing digital subscriber loop (DSL) providers as a network element.<sup>11</sup>

#### 4.2.1.4 "Cost-Based" Prices

Kahn, Weisman and Tardiff (Kahn et al., 1999) suggest that the Act provided minimal guidance on how the cost-based price for resale, UNEs and interconnection to the incumbent's local network should be set. They outline (at page 324-5) that amongst economists, there was:

...widespread agreement in principle that (1) the costs that would be the basis for efficient prices would be forward-looking, rather than historical and (2) the prices set on that basis should emulate the ones that would emerge from local exchange competition, if it were feasible.

Kahn et al., Weisman (2000) and Noam (2002), all note that there has disagreement over the appropriate FL cost standard to use. The incumbent carriers have argued that prices should reflect "actual" FL costs faced in providing inputs, while access seekers — the potential CLECs — maintained prices should be based on the "hypothetical efficient" FL cost of a firm entering the industry and constructing the network afresh, using the latest equipment and technology. Noam reflects the opposing sides taken in the debate, stating (at page 408) that:

Incumbent LECs generally argue that future costs should be based on each incumbent's existing network technology, not on some idealised least-cost, most efficient network that may bear no relationship to existing operations...Entrants, on the other hand, prefer forward-looking prices at least as long as costs are declining over time.

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<sup>11</sup> Noam (2002) at page 396.

To provide an illustration of the different asset valuations that can arise under BL, actual FL and hypothetical efficient FL cost regulation, a simple example is highlighted in Box 4.2.1.

**BOX 4.2.1 BL, ACTUAL FL AND HYPOTHETICAL EFFICIENT FL COST REGULATION**

To highlight the different valuations that can arise under BL, actual FL cost and hypothetical efficient FL cost, it is assumed for simplicity here that the incumbent undertakes an investment in a  $T$ -period lived asset at time 0, at a cost of  $C_0$ . For simplicity there is neither any physical deterioration on the asset, nor any inflation, but there is a known constant rate of cost-decreasing technological progress of  $\theta > 0$ . This implies that at any time  $t$ , the cost of replacing the asset using the **existing technology** of the incumbent will be  $C_t = C_0(1 - \theta)^t$ , where  $t = 1, 2, \dots, T$ . At time  $t_1 < T$ , however, a **new technology** is discovered. If this were used to replace the incumbent's asset at time  $t_1$ , the investor would face a cost of  $\hat{C}_{t_1} < C_0(1 - \theta)^{t_1}$ . As it is also assumed the new technology experiences the same constant rate of cost-decreasing technological progress  $\theta > 0$ , then at any time  $t$ , where  $t = t_1, \dots, T$ ; the cost of replacing the incumbent's asset using the new technology is  $\hat{C}_t = \hat{C}_{t_1}(1 - \theta)^{t-t_1}$ . Subsequently, at any time  $t = t_1, \dots, T$ , the different types of regulations will lead to the incumbent being subject to the following asset values:

**BL cost regulation:**  $C_0$

**Actual FL cost regulation:**  $C_t = C_0(1 - \theta)^t$ , where  $t = t_1, \dots, T$

**Hypothetical efficient FL cost regulation:**  $\hat{C}_t = \hat{C}_{t_1}(1 - \theta)^{t-t_1}$ , where  $t = t_1, \dots, T$

In August 1996 the Interconnection Order issued by the FCC outlined that the regulator had chosen to interpret the legislative requirement for cost-based prices, as meaning that the firm would be allowed to recover the costs associated with reconstructing a network using the ILEC's existing wire centres and "the most efficient technology" available.<sup>12</sup> In accordance with this, the FCC prescribed that the forward-looking-cost-based charge approximating the long-run marginal cost — the total-element-long-run-incremental-cost (TELRIC) method — should be used for regulating access to UNEs. TELRIC represents, the additional or incremental cost to the firm of providing a network element in the long run, assuming that all other production activities remain unchanged. Kahn et al. and Weisman (2000) considered the decision by the FCC to adopt TELRIC to be an endorsement of the hypothetically-efficient FL costs proposed by access seekers.

<sup>12</sup> See Sidak and Spulber (1997a) at page 420, which cites a passage from the *First Report and Order* on interconnection issued by the FCC.

#### 4.2.2 A Brief History of Australian Telecommunications

Unlike the US, for the majority of the twentieth century, State-owned monopoly providers were responsible for supplying telecommunications services in Australia. For the purposes of the analysis, the changes in the telecommunications market are divided into three periods:

- prior to 1988, where state-owned monopolies provided telecommunications services;
- between 1988 and 1997, where there was a transition from having only state-owned monopolies, to having a limited amount of managed competition; and
- 1997 reforms, which have led to an increased level of competition in the market.

Much of the information provided here is taken from Chapter 9 of King and Maddock (1996), Chapter 6 of Albon, Hardin and Dee (1997), and Appendix A of the Productivity Commission (PC, 2001a) inquiry report into *Telecommunications Competition Regulation*.

##### 4.2.2.1 The Market Prior to 1988

From 1901 to 1975 the provision of Australian domestic telecommunications by the Government was combined with the provision of mail services, and the responsibility of the Postmaster-General's (PMG) Department. The Australian Telecommunications Commission (Telecom) was established in 1975, and resulted from the Government separating the telecommunications and postal parts of the PMG Department. It had a monopoly or exclusive right to provide, operate and invest in the telecommunications infrastructure servicing land-based domestic telephony.

The Overseas Telecommunications Commission (OTC) was established by the Commonwealth in 1946, and was responsible for international telecommunications services. It had an exclusive right to provide and operate all services over the international network, but was prohibited from using the domestic infrastructure, and paid Telecom for carrying its calls over the domestic network. The Australian domestic communications satellite system (AUSSAT) was formed in 1981, and this owned and operated Australia's communication satellite. While it provided services that interconnected with Telecom's network, it was not permitted to compete with Telecom in supplying standard domestic phone services.



#### 4.2.2.2 Reforms from 1988-1997

The first of many of the major changes to the telecommunications market occurred in 1988. The reforms included:

- the regulation of telecommunications services, including the pricing of interconnection to the network, being transferred from Telecom to an industry-specific regulator for telecommunications — the Australian Telecommunications Authority (AUSTEL);
- opening up customer premises equipment (CPE) and value added network services (VANS) to competition; and
- changes being made to the corporate structures of Telecom, OTC and AUSSAT. In particular, the corporatisation of Telecom provided it with a more commercial focus, and clearer objectives to operate in a more business-like manner.

In 1990, further reforms led to the establishment of the Telecommunications Act 1991. The legislation was aimed at providing a platform from which sustainable competition would eventually evolve in the telecommunications market in Australia. Accordingly, a duopoly was introduced in fixed line carriage, which was shielded from competition and provided with certain exemptions from the anti-competitive conduct provisions in Part IV of the Trade Practices Act (TPA). The duopoly was allowed to operate until June 1997 and consisted of:

- **the publicly-owned Australian Overseas Telecommunications Commission (AOTC) — which was later known as Telstra.** This was formed by amalgamating Telecom with OTC in 1992, to create a vertically-integrated telecommunications service provider. According to King and Maddock (at page 137), by creating a vertically-integrated provider and introducing full network competition, Australia “followed the British example fairly closely”. The choice of market structure was however in direct contrast to the US model, which had chosen to pursue vertical separation, by implementing the break-up of AT&T in 1984. In 1997, Telstra was floated and one-third of its shares sold;<sup>13</sup> and
- **the privately-owned Optus, which purchased a complete carrier licence along with the fully-privatised AUSSAT.** It paid Telstra to carry calls on its behalf over the local network.

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<sup>13</sup> The Federal Government offered a further float of Telstra in 1999. At present it is still the majority shareholder in Telstra.

In addition to Telstra and Optus, a third mobile licence was allocated to Vodafone, which commenced its operations in 1993.

Although Optus initially established its own long-distance network, it relied on Telstra's network to reticulate its long distance and international calls at a local level. As the carriers were unable to agree on the terms for interconnection to the local network, AUSTEL was required to act as an arbitrator. This led to a regulated access price loosely based on the long-run marginal cost of providing access to the network.<sup>14</sup> Optus eventually offered local call services using Telstra's network in 1996, and soon after established its own local network in certain urban areas.

#### 4.2.2.3 *The 1997 Reforms*

To build on the 1991 reforms to the Australian telecommunications market, the Telecommunications Act 1997 was introduced, along with telecommunications-specific provisions to the TPA in Parts XIB and Parts XIC. This led to a number of important changes in the industry. Amongst the major reforms to the telecommunications market was that:

- restrictions on carrier licences were removed;
- new regulatory arrangements were introduced; and
- a telecommunications-specific anti-competitive conduct code and access regime were incorporated into the TPA.

The Telecommunications Act 1991 allowed only two providers to offer fixed-line carriage, and three providers to offer mobile telephony services. The 1997 reforms ended this arrangement, removing and reducing the exclusive rights held by the three providers. Carriers were no longer exempt from general competition law, and regulatory barriers to becoming a carrier were removed. As the PC (2001a) highlights (at page 591), the impact of this lower barrier to entry was that “while there were only three licensed carriers between 1991 and 1997, there were 77 at the end of June 2001.”

The telecommunications-specific regulator AUSTEL ceased its operations in 1997. Its responsibilities were then transferred to the Australian Competition and Consumer Commission (ACCC) and the new body, the Australian Communications Authority (ACA). The ACCC undertook the responsibility for dealing with competition issues in

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<sup>14</sup> See PC (1997) at page 75, which also cites King and Maddock (1996) at page 139.

telecommunications, which included administering the new access arrangements, while the ACA became responsible for consumer, technical and spectrum management issues. In accordance, with its new role, the ACCC issued an access pricing principles paper for telecommunications — ACCC (1997). This outlined that in general, the FL cost-based total-service-long-run-incremental-cost (TSLRIC) method should be used to price access to the network. Designed to approximate the long-run marginal cost, the ACCC (1997) defines TSLRIC (at page 28) as

...the incremental or additional costs the firm incurs in the long term in providing the service, assuming all of its other production activities remain unchanged. It is the cost the firm would avoid in the long term if it ceased to provide the service.

The regime is used to regulate interconnection prices to the public switched telephone network (PSTN) and is similar to the TELRIC access regime employed by the FCC.

The exemptions established in 1991 from Part IV of the TPA dealing with anti-competitive conduct, were repealed in 1997. However, concerns about the effectiveness of Part IV to constrain anti-competitive conduct in the gradually developing competitive market of telecommunications, where there was a vertically-integrated service provider Telstra, led to Part XIB — a telecommunications-specific regime for regulating anti-competitive conduct — being added to the TPA.<sup>15</sup> For similar reasons, although Part IIIA of the TPA already provided a national access regime for a range of infrastructure, a telecommunications-specific access regime was established in Part XIC of the TPA.<sup>16</sup> Part XIC requires that for access to be made available a service must first be “declared”. Generally, the ACCC undertakes an inquiry to determine whether declaration is in the public interest. If it is, then a service will be declared, and access to it must be provided.<sup>17</sup> Although certain services have been declared and subject to regulated access by the ACCC — such as the unconditioned local loop (ULL) — others have not been declared — such as the domestic inter-carrier roaming on digital mobile networks.

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<sup>15</sup> This legislation was designed to operate in conjunction with Part IV of the TPA. While Part XIB is similar to Part IV of the TPA, it is easier show a breach of anti-competitive conduct under Part XIB than under Part IV. See Chapter 5 of PC (2001a) for further details.

<sup>16</sup> Parts XIC and IIIA of the TPA are similar and both apply to telecommunications, although Part XIC has priority. See Chapter 7 of PC (2001a) for further details.

<sup>17</sup> One difference between Part XIC and Part IIIA of TPA outlined by the PC (2001a) at page 595 is that, once a service is declared, Part XIC gives greater rights to the access seeker.

The 1997 reforms have played a crucial role in the development of competition in the Australian telecommunications market. Importantly, these reforms have formed the basis of the regulatory regime that is presently used in the industry today. The PC (2001a) highlights this point when it states (at page 590) that:

The current framework for regulating telecommunications was largely set in place in 1997, when further policy changes intended to enhance competition came into operation.

### 4.3 The TELRIC/TSLRIC Prices

Section 4.2 notes that both the FCC and ACCC chose FL cost-based prices designed to approximate the long-run marginal cost, to regulate the access prices of interconnecting to the network. The FCC employs the total-element-long-run-incremental-cost (TELRIC) method, while the ACCC has adopted an access regime based on the total-service-long-run-incremental-cost (TSLRIC) method. While there are important differences between the two access regimes,<sup>18</sup> many economists have chosen to use the terms interchangeably when criticising TELRIC and TSLRIC.<sup>19</sup> For example, Sidak and Spulber (1997a) note (at page 404) that,

To avoid redundancy, and because the economic analysis is the same in either case, we subsume our critique of TELRIC pricing within that of TSLRIC pricing.<sup>20</sup>

As this Section only provides a brief overview of the cost concepts, and the majority of the Chapter is focused upon assessing the many criticisms of TELRIC and TSLRIC, the analysis here also uses the two terms interchangeably.<sup>21</sup>

This Section looks at the basic theory underlying TELRIC/TSLRIC prices and examines the inputs that are used to calculate TELRIC/TSLRIC prices in practice. It outlines some of justifications for the use of the FL cost-based regime provided by regulators in the US and Australia, and recounts Pelcovits's (1999) tracing, of the rise of the "bottom-up" engineering-cost models used to determine the TELRIC/TSLRIC prices.

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<sup>18</sup> Gans and King (2003b) have recently highlighted theoretical and practical differences in the calculation of TSLRIC and TELRIC. They outline that, in terms of the theory, TELRIC and TSLRIC appear to treat common costs differently. Gans and King maintain (in their Executive Summary) that as a result, TELRIC-based prices may lead to "some services...artificially cross subsidising other services." They also raise concerns (at page 19) that in practice, the estimates of TELRIC obtained in Australia from using Telstra's PIE II cost-model, "will systematically overstate" the true TSLRIC-based access charge.

<sup>19</sup> Kahn, Weisman and Tardiff (Kahn et al. 1999) refer (at page 326, footnote 14) to TELRIC as "a variant of the more widely known 'total-service long-run incremental cost' — TSLRIC."

<sup>20</sup> Sidak and Spulber though, do go on to immediately state (at page 404) that, "there is an important difference between TSLRIC and TELRIC that should be noted". They outline that while TSLRIC prices the outputs and services, TELRIC prices inputs of the firm. Therefore, according to Sidak and Spulber (at page 404), the choice of TELRIC by FCC "represents a significant increase in regulatory control" and "an additional level of regulator intrusiveness".

<sup>21</sup> The PC (2001a) notes (at page 622, footnote 1) that the TELRIC and TSLRIC "distinction is somewhat arbitrary", and provide an example of the ACCC using TSLRIC, yet costing network elements such as the local loop.

### 4.3.1 The Theory Behind TELRIC/TSLRIC Prices

#### 4.3.1.1 Long-Run Marginal Cost

The long-run marginal cost of service  $A$  ( $LRMC_A$ ) represents the increase in the costs of production as a result of a small increase in the level of output of service  $A$ . As it is the long run, all costs are variable and the long-run marginal cost will include compensation for the firm's opportunity cost of capital. In a perfectly-competitive market, pricing service/element  $A$  at its long-run marginal cost induces the efficient outcome, as the price paid reflects the additional opportunity cost to society of the resources that are required to produce a small increase in output

#### 4.3.1.2 Long-Run Incremental Cost

Linhart and Webber (1997) note (at page 8) that as technically long-run marginal cost is a derivative, in practice it is the long-run incremental cost that is used to measure changes in cost. Baumol and Sidak (1994) outline (at page 57) that the long-run incremental cost of service  $A$ , is the change in the firm's total costs when the output of service  $A$  is increased by some pre-selected increment. They note that the incremental cost will approximate the marginal cost for a small increment, but may differ substantially from marginal cost over a larger increment.

#### 4.3.1.3 Total-Service/Element-Long-Run Incremental Cost

If the cost of the firm providing all services/elements  $A, B, C$  etc is  $C(q_A, q_B, q_C, \dots)$ , then the total-element/service-long-run increment cost of the firm providing the entire service/element  $A$ , can be expressed,

$$\text{TELRIC/TSLRIC}_A = C(q_A, q_B, q_C, \dots) - C(0, q_B, q_C, \dots) \quad (4.3.1)$$

As the final TELRIC/TSLRIC-based price is often expressed on a per-unit basis (e.g. access to the PSTN is expressed in cents per minute), the expression in equation (4.3.1) is typically divided by quantity. This gives, an expression for the long-run average incremental cost of providing service/element  $A$  (i.e.  $LR(A)IC_A$ ) of,<sup>22</sup>

$$LR(A)IC_A = \frac{\text{TELRIC/TSLRIC}_A}{q_A} = LRMC_A \quad (4.3.2)$$

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<sup>22</sup> The concept of long-run average incremental cost has its origins in the contestable markets literature, and in the US has been used as the basis for determining the price floor in the regulation of both rail and long-distance telecommunications access.

The long-run average incremental cost provides an approximation of the long-run marginal costs, and regulators sometimes refer to it as the TELRIC/TSLRIC-based price. From equation (4.3.2), it is apparent that the long-run average increment cost is marginal with respect to the service, but not with respect the units of output the service, and is equal to the long-run average cost of production if there is only one service or element.

Gans and King (2003b) make the important point (at pages 7-8) that in practice, the calculation of TELRIC/TSLRIC by regulators is “technology-dependent”. That is, the TELRIC/TSLRIC calculation could be based on either the old BL cost technology, or the new FL cost technology. As regulators across a number of countries have chosen to apply FL costs when using TELRIC/TSLRIC, there is now a general presumption that it refers to a FL cost-based access price.

#### 4.3.2 Calculating TELRIC/TSLRIC Prices in Practice

The FL TELRIC/TSLRIC estimate assumes that as in a long-run competitive local exchange market — i.e. where there are many access providers each supplying interconnection services to their networks — all costs associated with the incremental element or service are variable and minimised. To calculate the TELRIC/TSLRIC price a “bottom-up” approach is used. That is, to determine the FL cost-based access price, an engineering-cost model is employed that estimates the cost of re-optimising or reconstructing the network.<sup>23</sup> To do this, various simplifying assumptions are made about the location of the network and the technology it incorporates.

Generally, to calculate TELRIC/TSLRIC, regulators in the US and Australia adopt what the ACCC refer to as a combination of a “scorched-node” approach and “best-in-use” technology.<sup>24</sup> The scorched-node approach means that the existing switch locations of the incumbent’s network are held fixed. This is in contrast to a “scorched earth” approach, where switch locations are variable, and the regulator is not constrained to

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<sup>23</sup> Engineering cost models such as those used in telecommunications are not new to regulated industries in the US. Since the *Coal Rate Guidelines* issued by the ICC in 1985, similar cost models have been adopted to assess access prices for rail transportation services.

<sup>24</sup> The PC (2001a) at page 626-7 outlines that this is method used by the ACCC in estimating the efficient FL costs. It appears from Kahn et al. that the FCC has stipulated a similar method. They note (at page 326, footnote 14) that the FCC estimates the FL costs of the incumbent local network holding the location of existing wire centres of the incumbent local exchange carriers fixed.

basing costs on the existing location of the incumbent's network. The assumption of best-in-use technology means that the regulator will use the most efficient technology that is commercially available and compatible with the existing network design.<sup>25</sup> This could just involve using the FL cost estimates of the technology that is presently incorporated into the incumbent's network. In contrast, the assumption of "best-available" technology requires the regulator to optimise the network using the very latest telecommunications equipment, some of which may not have been deployed in any existing telephone network.<sup>26</sup>

To compute TELRIC/TSLRIC using the engineering-cost model, estimates are required for the current value of the capital equipment; the ongoing efficient FL operating and maintenance expenses; the likely pattern of future usage; and the opportunity cost of capital — which includes a market rate of return on an investment of commensurate risk and an allowed depreciation rate. In addition, there will be certain costs that cannot be directly attributed to any specific service or element of the network. As the standard TELRIC/TSLRIC calculation does not account for these FL joint and common costs, both the FCC and ACCC stipulate that the access price should include a mark-up above the basic TELRIC/TSLRIC price.<sup>27</sup> The ACCC refers to the resulting price that takes into account this mark up as TSLRIC+. As the ACCC also provides a further mark-up on terminating and originating PSTN access charge to allow recovery for some portion of the access deficit — i.e. the loss from the below-cost regulated prices applying to local services — the resulting access charge to the PSTN is known as TSLRIC++.<sup>28</sup>

#### 4.3.3 Justifications of the TELRIC/TSLRIC Model

Regulators have highlighted the benefits of TELRIC/TSLRIC, by emphasising that the scheme provides an estimate of the long-run marginal cost of supplying a service or

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<sup>25</sup> See the ACCC (1997) at page 30.

<sup>26</sup> The ACCC (1997) makes it clear that it does not subscribe to the "best-available" technology approach. It states (at page 30) that, "in estimating TSLRIC the Commission will not use experimental prototypes as a benchmark for best-in-use technology."

<sup>27</sup> The PC (2001a) highlights these components of TSLRIC at page 623 in Box D.1.

<sup>28</sup> The ACCC (2000a) outlines (at page 414) that the national weighted average TSLRIC++ estimate for 2000-01 was 1.53 cents per minute. The access deficit contribution (ADC) made up 0.69 cents per minute, or (as the PC (20001a) notes) 45 per cent of this access charge. The recent ACCC (2003) document highlights that there is presently an ongoing debate about the appropriateness of having an ADC in the access charge. It is interesting to note that in the US, there is no such similar mark-up allowed in the access price to account for the equivalent deficit experienced in the local telecommunications market.



element. TELRIC/TSLRIC through approximating the long-run marginal cost of production:

- prevents the access provider from charging a monopoly rate for access to the network;
- allows the firm to recover all relevant incremental costs associated with supplying the element or service — including a fair rate of return on its invested capital; and
- roughly captures the efficiencies associated with pricing at the long-run marginal costs.

As the access regime balances the competing needs of maximising benefits to the consumer while still ensuring cost recovery on the investment for the regulated firm, regulators in the US and Australia assert that the TELRIC/TSLRIC price will be:<sup>29</sup>

- **allocatively efficient.** By restricting the market power of the vertically-integrated monopoly and basing price on the cost to society from providing the investment, the regime induces the efficient use of the existing infrastructure;
- **production efficient.** Through using the efficient FL cost technique combining a scorched node and best-in-use technology approach, the regime promotes incentives for the access provider to minimise the cost of providing access. It ensures the firm cannot expect to recover inefficiencies in production; and
- **dynamically efficient.** By compensating the infrastructure for its opportunity cost of capital, it encourages the economically efficient future investment in infrastructure and promotes the efficient ‘buy or build’ decisions by entrants to the industry. Further, it rewards the firm for undertaking innovations or adopting technologies that are more efficient than those that are commercially available.

Pelcovits (1999) argues that a further advantage of the TELRIC/TSLRIC model is that, compared to the original “black box” models offered by incumbent local exchange carriers in the US, they are open, transparent, and easily tested for sensitivities to inputs and assumptions. By using FL costs, he claims TELRIC/TSLRIC models avoid many of the controversial cost allocations associated with compensating the incumbent for its embedded historical cost. Pelcovits provides a brief historical account tracing the rise

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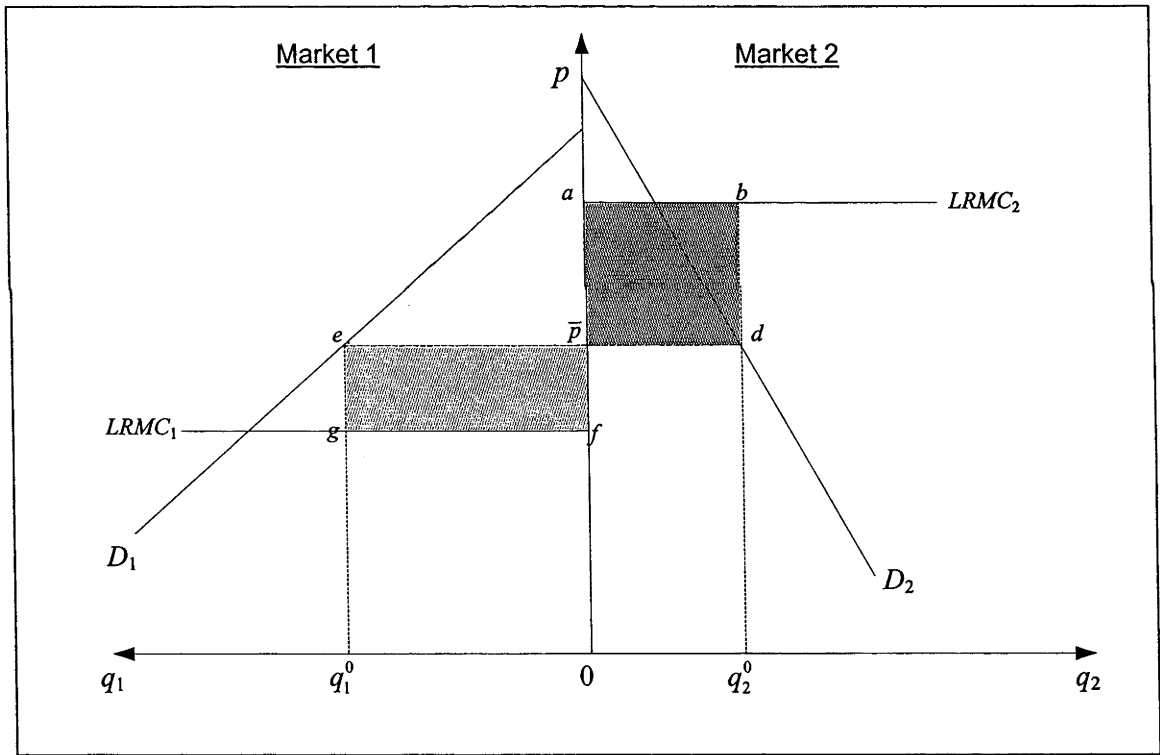
<sup>29</sup> This summarises the six benefits of using TSLRIC outlined by the ACCC (1997) at pages 29-30.

of engineering-cost models in telecommunications. This is outlined in the following sub-section.

### 4.3.4 The Rise of the Engineering Cost Model — Pelcovits (1999)

According to Pelcovits (1999), the development of engineering-cost models, and their eventual adoption in the telecommunications industry, arose from the regulator’s and potential entrants’ continuing frustrations with incumbent firms over-stating the costs that they should be allowed to recover. He highlights that one of the original forays into cost models came about as a response to the lack of transparency associated with the rates proposed for universal service obligations (USOs) by ILECs in a 1993 United States Telephone Association (USTA) report.<sup>30</sup>

FIGURE 4.3.1 A UNIVERSAL SERVICE OBLIGATION



Pelcovits’s arguments can be highlighted with the assistance of a diagram. Figure 4.3.1, depicts a USO that requires a uniform price  $\bar{p}$  across a low-cost market (market 1) and higher-cost market (market 2). In market 1, the quantity  $q_1^0$  is demanded at price  $\bar{p}$ ,

<sup>30</sup> Noam (2002) also notes (at page 396) that the engineering cost models used for TELRIC calculations were “developed initially for the calculation of universal service cost allocations.”

and the firm makes a profit of  $e\bar{p}fg$ . Some portion of these profits is used to subsidise the consumers in market 2, so that the quantity  $q_2^0$  is demanded at price  $\bar{p}$ .

In this USTA report, incumbent firms argued that to assess the USO contributions potential entrants should make, rather than measuring the size of the losses directly from subsidised groups (i.e. area  $abd\bar{p}$  in Figure 4.3.1), the regulator should estimate the amount by which revenues exceed costs in profitable markets (i.e. area  $e\bar{p}fg$  in Figure 4.3.1). Implicitly, this argument relies on the incumbent firm originally being on a financial “knife-edge”. That is, prior to entry being allowed, the incumbent is only making normal returns on the asset as all revenues from services where price exceeds cost are devoted to subsidising those services where rates are being held below cost (i.e. area  $e\bar{p}fg$  is equal to area  $abd\bar{p}$  in Figure 4.3.1). This reasoning led the incumbent local network owners to conclude that compensation in the order of US\$20 billion per year was required if competition were to be allowed in its profitable markets. In response to this claim a competing carrier, MCI, commissioned Hatfield Association Inc. to construct a stylised engineering-cost model. It estimated the losses actually incurred by the incumbent in the unprofitable market (i.e. area  $abd\bar{p}$ ). Instead of the US\$20 billion figure, this model estimated that the entrants should pay a subsidy of US\$3.7 billion per year.<sup>31</sup>

The discrepancy between the figures in the example offered by Pelcovits suggests that the incumbent was originally making above-normal returns, and that the TELRIC/TSLRIC cost models evolved as a regulatory and potential entrants’ response to attempts by incumbents to retain existing rents in the pricing of their services. While Hausman (1999b) does not dispute the facts raised by Pelcovits, he does respond to the overall tone of the article, which predominantly argues that incumbent local exchange carriers have systematically discredited FL cost models in an attempt to bring back historical cost-based prices. In relation to this claim, Hausman states (at page 250) that “conspiracy arguments are looked upon much more favourably within the Beltway than in academia.”

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<sup>31</sup> In Australia, estimation of the USO led to a similar discrepancy. The PC (2001a) outlines (at page 600, Box A.4) that in 1998 Telstra estimated that the cost of providing universal services was \$1.8 billion. The Government however capped the USO cost at \$253 million.

## 4.4 Criticisms of TELRIC/TSLRIC Prices

A recurring strategy of almost all critiques of TELRIC/TSLRIC in the US and Australia, is an attempt to explain why regulation leads to the under-pricing of access, and then to highlight the various inefficiencies associated with having such “below-cost” rates. Consequently, in this Section, after outlining the controversy that has surrounded TELRIC/TSLRIC-based prices in the US and Australia, the analysis examines the:

- (1) reasons given for why TELRIC/TSLRIC under-prices access; and
- (2) consequences of setting a TELRIC/TSLRIC-based access price.

The sub-division of categories used here to present the arguments made against TELRIC/TSLRIC regulation, is at times, very similar to the framework of Kahn et al. (1999). While there will be some overlap between the arguments contained in each of the sub-categories, this analysis aims to provide a clear overview for why the regulated access price is associated with below-cost rates and harm to efficiency. Further, although many of the criticisms outlined here are directed towards the US access regime, it is illustrated throughout that almost identical arguments have been raised in Australia.

### 4.4.1 The Controversial TELRIC/TSLRIC

In the US, the controversy surrounding the introduction of TELRIC/TSLRIC has been evident in the protracted series of regulatory disputes and legal challenges brought against the regime. A verdict delivered by the Eighth Circuit Court in 1999 initially rejected the TELRIC/TSLRIC approach to pricing. This held that rates for access should be based upon the directly-attributable actual incremental costs of production.<sup>32</sup> The US Supreme Court overturned this decision in the case of *Verizon v FCC*,<sup>33</sup> reaffirming the right of the FCC to set regulated access prices using TELRIC/TSLRIC, and to incorporate the FL costs of a hypothetically-efficient firm.

A number of prominent economists in the US have criticised the FL cost standard used to price access to local network elements. These critics have labelled TELRIC/TSLRIC

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<sup>32</sup> *AT&T Corporation v Iowa Utilities Board*, 525 U.S. 366 (1999).

<sup>33</sup> *Verizon Communications Inc. v Federal Communications Commission*, 122 S.Ct 1646 (2002).

as: a political process wrapped in the guise of efficient regulation;<sup>34</sup> a regime that recasts the regulator in the role of a central planner;<sup>35</sup> an attempt by regulators to micromanage the process of telecommunications liberalisation;<sup>36</sup> an act of astounding *regulatory presumption*;<sup>37</sup> a “back-to-the-future” version of cost-based regulation;<sup>38</sup> confusing the mandating of the competitive outcome with fostering the competitive outcome;<sup>39</sup> a scheme with a broad regulatory consensus that is supported by little economic argument;<sup>40</sup> and an “anti-patent” system where the regulator speculates what the competitive market costs should be.<sup>41</sup>

The introduction of TSLRIC by the ACCC met with similar disapproval, and many of these criticisms have been repeated in Australia. This was evident in both the submissions to the Productivity Commission inquiries into *Telecommunications Competition Regulation* and the *National Access Regime*, and from the respective final reports issued by the Productivity Commission — PC (2001a) and PC (2001b).

#### 4.4.2 Reasons why TELRIC/TSLRIC Under-prices Access

In both the US and Australia, access providers have consistently maintained that TELRIC/TSLRIC-based access prices are set below cost. For example, the PC (2001a) highlights (at page 622) that the “main concern” in Australia has been that “the ACCC’s application of TSLRIC under-estimates the access prices required to provide an adequate commercial return on investment.”<sup>42</sup> The PC also notes (at page 393, Box 11.3), Telstra’s claim that:

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<sup>34</sup> Crandall and Hausman (2000) at page 98.

<sup>35</sup> Weisman (2000) at page 210.

<sup>36</sup> Crandall and Hausman (2000) at page 109.

<sup>37</sup> Kahn et al. (1999) at page 328 and Kahn (2001) at page 5.

<sup>38</sup> Kahn et al. (1999) at page 331.

<sup>39</sup> Weisman (2000) at page 197.

<sup>40</sup> Laffont and Tirole (2000) at page 148.

<sup>41</sup> Kahn et al. (1999) at page 349 and Weisman (2000) at page 209.

<sup>42</sup> In Section 5.3 of Chapter 5, a formal model is used to show how FL cost regulation can potentially under-price access.

After nearly 3 years of TSLRIC modelling, the ACCC has produced interconnect charges that are unreasonably low by any standard.

From examining a number of the early critiques, it appears that the main reasons offered for this under-pricing occurs, are that:

(1) there are *prohibitive informational requirements for estimating TELRIC/TSLRIC*.

The detail and complexity of telecommunications networks means that regulators are forced to make arbitrary judgements about what constitutes efficient costs;

(2) it incorporates *unrealistic assumptions* in dealing with cost trade-offs, sunk costs, technological progress and demand for the industry;

(3) it is a form of *asymmetric regulation* and generates *asymmetric risk*; and

(4) the *long-run competitive model is inappropriate as a benchmark to price access*.

Each of the above reasons is outlined in detail in the following sub-sections.

#### 4.4.2.1 *Prohibitive Informational Requirements for Estimating TELRIC/TSLRIC*

The eminent economist Alfred Kahn has characterised the FCC's approach to pricing as one of "TELRIC/TSLRIC-BS",<sup>43</sup> where the regulator determines the access price by rebuilding the network of the incumbent from the ground up. According to Kahn it is as if it the network were constructed on a blank slate (BS), with the one qualification that the regulator takes existing wire locations as given. Kahn et al. (1999) reflect the substantial amount of information and detail required in order to estimate TELRIC/TSLRIC at page 335.

Designed to produce the costs that a firm would experience over a period of time into the future, and especially as applied to complex telecommunications networks, the amount of detail they must incorporate — about the size and cost of central office switches, locations and cost of fiber optic electronics — are forbidding.

Along with the quantity of information, questions have been raised over the quality of the "efficient cost" information available to the regulator. Crandall and Hausman (2000) believe there are significant problems associated with the regulator mandating

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<sup>43</sup> For Kahn's reference to the TELRIC/TSLRIC "blank-slate" see, Kahn et al. (1999) at page 326-327, Kahn (2001) at page 3-24, and Kahn (2002) at page 43.

the efficient costs of provision. They query (at page 87) how the regulator will know if the arbitrated rates reflect BL or FL costs of network elements and services. Kahn et al. suggest that determining “efficient costs” could be more problematic for the regulator than the substantial amounts of information required. Following on directly from the passage cited above, they write (again at page 335) that:

The problem is not merely that their construction imposes tremendous information requirements. More fundamentally, they put the regulator in the position of having to decide what investments are prudent...

While the criticisms of Kahn et al. and Crandall and Hausman were directed towards the US regime, similar claims have been made in Australia. The PC (2001b) notes (at page 91) that it has been emphasised that “the information required for effective intervention can be particularly daunting if access prices are based on the ‘efficient’ cost of supply”. It then goes on to cite a passage from a submission to the *National Access Regime* inquiry by NECG (2001a), which states (at page 17) that:

Cost estimation is a formidable problem for regulation even when the actual costs of the regulated firm are the focus. It is significantly more difficult to accurately estimate the capital cost of a hypothetical, efficiently configured, asset.

As outlined in Chapter 2, during the 1980s and early 1990s, regulators in the US, UK and Australia all moved towards adopting the more incentive-based and light-handed price-cap regulation for telecommunications. Aside from the purported production efficiency gains, according to Kahn et al. and Weisman, the adoption of price-cap regulation suggested that regulators had realised that they did not have the necessary information to anticipate, independently and accurately, the efficient operating and capital costs the firm should be allowed to recover. By applying the hypothetically-efficient cost standard, TELRIC/TSLRIC is associated with the reintroducing a major flaw of rate-of-return (ROR) regulation, as it forces the regulator to determine what constitutes a prudent investment.<sup>44</sup> The only difference to traditional ROR regulation is

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<sup>44</sup> It should be noted that although a rate of return is obviously required in the calculation of TELRIC/TSLRIC, in the US the 1996 Telecommunications Act explicitly contemplated that traditional US-style ROR regulation, which had been phased out in the early 1990s, should not be used. In Section 252(d)(1)(A) of the Act, it was outlined that TELRIC-based access prices should be “determined without reference to a rate-of-return or other rate-based proceeding.”

that this decision must now be made prior to the investment actually being undertaken. According to Kahn et al. and Weisman, regulators are substituting their judgement for that of management, and relying upon the FL cost standard, to bring about the same efficiency gains that were originally achieved by providing market-based incentives under price-cap regulation. As the model uses information not appreciably different from that required under ROR regulation — i.e. estimates of the cost of capital, depreciation rate and economic life of the capital asset — TELRIC/TSLRIC has been described by Weisman (2000) as a “major retrogression” from price-cap regulation,<sup>45</sup> and by Kahn et al. as a “back-to-the-future” version of ROR regulation.<sup>46</sup>

#### 4.4.2.2 *Unrealistic Assumptions*

TELRIC/TSLRIC has been criticised on the basis that it incorporates highly unrealistic assumptions in modelling and estimating the costs that an access provider should be allowed to recover. The use of hypothetically-efficient FL costs, combined with the assumption that the local exchange is characterised by a world of certainty, has led to TELRIC/TSLRIC being responsible for:

- **failure to take into account** the important **cost trade-offs** within the firm; and
- **failing to capture** the significant **sunk costs** of the network, the **technological progress** within the industry, and **changes in demand and price**.

In the US there has been criticism over the regulator’s decision to use the FL costs of a hypothetically-efficient firm rather than the actual FL costs of the incumbent network provider. For example, while the FCC examines all actual FL cost data provided by the incumbent and the competing local exchange carriers, it is alleged that it determines the costs of a hypothetically-efficient firm by simply selecting the lowest FL cost estimate associated with operating each component of the element or service being provided. Kahn et al. criticise this “pick and choose” approach to regulation on the basis that it ignores the ubiquitous interdependencies or **cost trade-offs** amongst the several FL cost components of an actual firm. By assuming that the “efficient firm” excels in all

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<sup>45</sup> See Weisman (2000) at page 200.

<sup>46</sup> See Kahn et al. (1999) at page 331.



aspects of its operations, TELRIC/TSLRIC fails to capture that a firm may have a low cost in one area, at the expense of having a higher cost in another.<sup>47</sup>

Kahn et al. claim that the combined effect of the Telecommunications Act and the TELRIC/TSLRIC-based access price is to create a regime where, the incumbent local network provider no longer receives the protection of being a monopoly, nor any assurance of cost recovery. The competitive framework means that the ILECs must now face the standard demand, price and technological uncertainty often associated with substantial sunk and irreversible investments.<sup>48</sup> As the regulator does not take the changed circumstance of the access provider into account, TELRIC/TSLRIC fails to compensate the incumbent for **sunk costs** and changes in **technology, demand and price**. This view is reflected in the following passage from Hausman (1997, at page 31) and Hausman (1999a, at page 196), who states:

TSLRIC assumes that all capital invested now will be used over the entire economic life of the new investment and that prices for the capital goods or the service being offered will not decrease over time. With changing demand conditions, changing prices, or changing technology, these assumptions are not necessarily true.... Significant economic effects can arise from the effects that the sunk nature of investment has on the calculation of TSLRIC.

Hausman (1997, 1999a) claims that TELRIC/TSLRIC does not take into account the **sunk and irreversible** nature of telecommunications investments, because it is based on the assumptions of a perfectly contestable market — a market where there are no sunk costs of production, and the mere threat of entry induces a competitive market outcome. Consequently, the FCC's standard assumes all network investments are made up of fixed not sunk costs, which are not subject to the same types of technological or economic uncertainty. Hausman maintains that these assumptions imposed by the regulator are clearly inconsistent with the economic reality of the local exchange market, and lead to the firm not being compensated adequately for its investment.

In a similar vein, Kahn et al. highlight that a problem of using the efficient costs of a hypothetical firm is that, in reality, to embody the most recent technology from the

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<sup>47</sup> See pages 332-334.

<sup>48</sup> Kahn et al. (1999) at page 336.

ground up, an incumbent provider must incur significant sunk costs. Unlike Hausman, they suggest these sunk costs could be compensated for in the TELRIC/TSLRIC prices. This can be done if the regulator allows the network access provider to recover a high enough rate of regulatory depreciation on the asset. However, Kahn et al. consider (at page 328-9) that such an outcome is unlikely to arise in practice, because there has been a tendency for TELRIC/TSLRIC models of the FCC to use traditionally-determined regulatory rates of depreciation and costs of capital, which are insufficient for achieving cost recovery.

Over the past few decades the telecommunications industry has been subject to a very rapid rate of **technological progress**. In addition to an increase in the variety and quality of telecommunications services, it has generally led to a decrease in the cost of providing existing elements or services. Hausman claims that the decrease in the price of the network components due to technological progress is not captured in the TELRIC/TSLRIC calculations. By doing this, the regulator effectively imposes a capital loss on the firm. As this loss is not compensated for in the access price the firm is allowed to charge by the FCC, the local exchange carrier is unable to recover costs associated with the investment.<sup>49</sup>

In experiencing a rapid rate of technological progress, Kahn et al. outline (at pages 336-7) that the telecommunications industry has followed a similar trend to the computer industry. Subsequently, they compare the monthly rental rate for hiring a personal computer with the monthly repayments required on a personal computer purchased outright on credit. This is done to highlight the perceived deficiency of the FL cost-based contracts at which the FCC has forced ILECs to offer their services and network elements.

In relation to the personal computer, Kahn et al. make the obvious point that the cost of leasing the computer on a short-term monthly contract will be higher than the monthly repayment required on a loan used to purchase the same computer outright. The reason for this is that under a short-term contract, the lessor — i.e. the party that loans the computer — must be compensated for bearing the cost of the depreciation of the asset or any risk of obsolescence, due to technological advancement. TELRIC/TSLRIC is

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<sup>49</sup> The model used in Chapter 5 captures this problem outlined by Hausman and that outlined by Kahn et al. in the preceding paragraph.

claimed not to appreciate this phenomenon in its pricing of network elements. The FL cost model bases the access price on a long-term contract, which matches the life of the essential infrastructure. In terms of the computer analogy, this price is equivalent to the monthly repayment required on a loan used to purchase the computer outright. However, according to Kahn et al., the regulator allows the access seeker to enter into short-term monthly contracts for access. The inconsistency between the implicit long-term contract underlying the access price, and the short-term contracts actually allowed for the lease of network elements, means that access is under-priced. The access provider here is not compensated for either the depreciation of the asset, or the risk of obsolescence that arises from technological progress.<sup>50</sup>

With respect to **demand**, the TELRIC/TSLRIC model typically assumes that the hypothetically-efficient firm just takes over the current volume and value of the ILEC's sales. It then dimensions the hypothetical network so that it can instantaneously supply that level of demand for the element or service at a minimum cost. This ignores that, in reality, telecommunications assets are generally long-lived and their capacity is not deployed all at once. Rather, it is expanded incrementally to serve the growing and changing levels of demand.

Alleman (1999, 2001) claims that, by using the TELRIC/TSLRIC model, the regulator is implicitly assuming that the demand for access is perfectly inelastic or unresponsive to changes in the access price. This arises because the regulator uses the efficient cost estimates to determine the maximum revenue the firm is allowed to earn, and then determines the access price by simply dividing this amount by an estimate for the level of demand. Consequently, no matter what the access price is, there is now no change in the quantity of access demanded. Instead of having the normal price-based quantities that emerge in markets, the regulator sets a quantity-based price for access. The failure of demand to change in response to any parameter in the model also implies that TELRIC/TSLRIC cannot deal with any type of **demand uncertainty**.

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<sup>50</sup> In a letter titled, "Change is as Good as an Access Holiday" appearing in the *Australian Financial Review*, 21 August 2001, Dennis O'Neill, the CEO of Australian Council for Infrastructure Development (AusCID), criticised the national access regime employed by the ACCC, using an analogous, yet much less eloquent argument. In relation to the current access-pricing regime used by the ACCC for telecommunications networks, gas pipelines, airport terminals and rail tracks, he stated:

It's like buying a new car and then being forced to let anyone drive it without paying for all the petrol they use. If you were an investor, you wouldn't buy the new car either.

The inability of the regulatory regime to cope with uncertain demand has also been emphasised in the work of Hausman (1997, 1999a) and Crandall and Hausman (2000). Crandall and Hausman argue that with either **demand or price uncertainty**, the current access-pricing regime inappropriately apportions the risk associated with the network investment. For example, under a fair price for access, if the expected level of demand in the downstream market did not materialise, or alternatively the price of the element decreased, the access seeker would be forced to bear the risk. Under TELRIC/TSLRIC though, because new entrants can lease UNEs on a month-by-month basis, they have the option of temporarily leaving the market if the anticipated level of demand does not materialise or the price of the element decreases. Therefore, in addition to their own business risk, ILECs are now being forced to bear the risk for the business case of their potential competitors.

#### *4.4.2.3 Asymmetric Regulation and Risk*

While Harris and Kraft (1997) outline that because TELRIC/TSLRIC uses an efficient-firm standard, it represents an asymmetric form of regulation that is biased in favour of the new entrant. However, others claim that the hypothetically-efficient FL cost standard is not only an asymmetric form of regulation, but imposes what they describe as an “asymmetric risk” upon the incumbent.

Weisman (2000), for example, argues (at page 199) that “asymmetric risk-bearing” arises because the ILEC must base its access price on a network superior to the elements that it is being required to unbundle. Weisman claims that this forces the access provider to bear all the risk of realising efficiency gains, without there necessarily being any market validation for their existence.

Kahn et al. suggest (at pages 341-2) that “asymmetrical risks” arise because the efficient-firm standard assumes that the network is configured instantaneously to serve whatever level of demand is forecast to arise. In reality, lags exist between the timing of the construction of the facility and the demand for access. Therefore, in practice, the incumbent incurs the sunk costs associated with building the essential infrastructure, and then faces the risks associated with whether or not the forecast demand actually materialises. By simply assuming this issue away, the regulator creates asymmetric risk. That is, it does not compensate the incumbent for the risks it was subject to when the investment was being undertaken.

In Australia, the Network Economic Consulting Group (NECG, 2001c) in its submission to the Productivity Commission Inquiry report on *Telecommunications Competition Regulation* has even suggested that asymmetric risk will arise as a direct consequence of having a TELRIC/TSLRIC access price that fails to recover cost. It claims (at page 13) that because the “wide-ranging discretion” afforded to Australian regulators, there has been:

...a degree of *regulatory* bias, in which a majority of decisions are made in favour of lower prices. This skews the distribution of expected returns, limiting the upside earnings potential and increasing the probability that revenues will fail to cover efficiently-incurred costs.

It asserts that to take the skewed return resulting from this bias into account, there must be a mark-up on the standard capital asset pricing model (CAPM) calculations.

The above approaches to regulatory or asymmetric risk should be contrasted with the argument of King (2000), outlined on pages 287-8 of PC (2001a). Unlike the previous arguments,<sup>51</sup> King does not suggest that the regulator engages in any systematic bias or asymmetric treatment of the firm. Instead, King uses reasoning similar to that of Kolbe, Tye and Myers (1993) and Kolbe and Tye (1995).<sup>52</sup> He demonstrates that the truncation of returns is endogenous to the process of having a regulator using an appropriately risk-adjusted expected rate of return to determine the maximum net cash flow the firm is allowed to earn in each period, when there is some form of uncertainty. The Productivity Commission notes that it may be necessary to provide the firm with a ‘truncation premium’ in order to compensate the access provider for what Kolbe, Tye and Myers (1993) have labelled ‘regulatory risk’, and Hausman and Myers (2002) have more recently described as ‘asymmetric risk’.<sup>53</sup> In practice this premium may be difficult to calculate, as the Productivity Commission notes that it requires a mark-up based on a probability-weighted allowed fair rate.<sup>54</sup>

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<sup>51</sup> NECG (2001c) also makes a case (at pages 9-10) that there will be regulatory risk even when the regulator is unbiased. Its arguments are summarised by the PC (2001a) at page 631 as saying that, under uncertainty and a concave profit function, unbiased price regulation will lead to systematic errors.

<sup>52</sup> Although their analysis specifically looked at the issue of stranded cost risk, their reasoning when applied more generally leads to the outcomes described by King and outlined in the Productivity Commission report.

<sup>53</sup> Small and Ergas (1999) outline that it is more appropriate to describe the problem of “truncation”, as a problem of the regulator “censoring” the returns of the access provider.

<sup>54</sup> See PC (2001a) at page 288 and PC (2001b) at page 299.

#### 4.4.2.4 Inappropriateness of Long-Run Competitive Model as a Benchmark

TELRIC/TSLRIC assumes that a long-run competitive market provides the appropriate benchmark for setting access prices in the local telecommunications market. However, this notion has been challenged by Kahn and Weisman, who maintain that the efficient-firm benchmark is inappropriate for regulating an industry, such as telecommunications, which experiences a rapid rate of technological progress. Citing passages from Schumpeter (1950), they argue that in an industry characterised by rapid technological progress, it is the prospect of the rewards of transient market dominance and monopoly pricing from successful innovation that provides the essential incentive for innovators and imitators alike. The FCC's approach, which requires innovators immediately to share their creations at prices based upon a perfectly-competitive market, fails to provide the necessary incentives. The regulator has established a regime that is described as being akin to an "anti-patent" system, which rewards imitation and free riding. Unlike a patent, which gives successful innovators exclusive use of whatever they invent, TELRIC/TSLRIC pricing instead forces investors fully to absorb the costs of unsuccessful ventures, yet deprives them of the fruits of successful innovations.

Kahn et al. allude to the work of Fellner (1958), and point out that in the extreme situation where there is a world of continual technological progress, firms may systematically practice what is known as "anticipatory retardation". That is, a firm only adopts the most modern technology when the progressively declining costs fall sufficiently below the currently prevailing prices, to offer an expectation of earning a return on the investment.

Schumpeter's arguments have also been employed in Australia to highlight flaws in the national access regime, and the lack of incentives it provides for innovation. For example the PC (2001b) cites (at page 67) a passage from Energex, which states that:

The Schumpeterian argument is that it is only the opportunity of higher returns than the perfectly competitive rate which will induce firms to undertake risky and uncertain investment and innovational activities...

In Australia, critics of TELRIC/TSLRIC have drawn upon the patent analogy to assert the need for an 'access holiday'. This represents a period of time where the investor is exempt from the service being declared, and the investment subject to any access regulation for a specified period of time.

The Productivity Commission examines the proposal of an access holiday in Chapter 9 of the *Telecommunications Competition Regulation* inquiry report, and Chapter 11 of the *National Access Regime* inquiry report. The PC (2001a) outlines (at page 287) that

the major argument contained in submissions is that, “an access ‘holiday’, like a patent, protects entrepreneurial returns that justify the investment in the first place”. It contemplates at pages 282-3 of PC (2001b), that if an access holiday were granted, it should apply for a minimum period of 15 to 20 years. Gans and King (2003a) recommend the use of an access holiday as a means for offsetting the ‘truncation problem’ associated with regulation, maintaining (at page 169) that:

...access holidays play a similar role to a patent in innovative activities....Both patents and access holidays are second-best solutions in that they impose a temporary monopoly cost on society. Both an optimal patent and an optimal access holiday needs to be designed to trade-off this temporary loss with the increased incentive to invest.

To simulate the outcomes of a long-run-perfectly-competitive industry and ensure that the firm earns a commensurate rate of return on assets of equivalent risk, the TELRIC/TSLRIC model adopts a standard neoclassical net present value (NPV) approach to the investment. Hausman (1997, 1999a) and Alleman (1999, 2001) criticise neoclassical theory on the basis that it does not account for the interaction between sunk costs and uncertainty — key features of the local telecommunications network investments. It subsequently ignores the value of managerial flexibility to address and adapt to various uncertainties as they arise. In the telecommunications industry, they argue that uncertainty may occur due to underlying economic parameters — such as technology, demand, price or interest rate — or due to the sovereign risks associated with regulation — such as the regulator changing or imposing unfair constraints on the firm. Due to these factors, both Hausman and Alleman advocate the use of real option theory to determine the appropriate regulated access price.

Real option theory contends that the ability of the investor to defer an irreversible and uncertain investment is something of significant value. It allows the investor to receive new information as time passes, which assists it in resolving some of the uncertainty that surrounds the investment. In effect the investor now has an option to delay the investment, similar to a financial option, known as an American call option.<sup>55</sup> The reason is it provides the firm with the opportunity, but not obligation, to undertake the investment at some future point in time. In these circumstances if the firm were to

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<sup>55</sup> Unlike financial options, real options are generally not tradeable.

invest, it would subject itself to an extra cost, as it destroys its option to wait. Dixit and Pindyck (1994) show that by taking into account this additional cost or call option to invest, the investment should only occur if the net present value is greater than zero.

It appears real option theory was first applied in telecommunications by Hausman in a written testimony provided to the California Public Utilities Commission (CPUC) in 1996.<sup>56</sup> Assuming uncertainty over revenue flows and basing his calculations largely upon the “reasonable parameters” of Dixit and Pindyck,<sup>57</sup> Hausman found that there was a 3.2-3.4 times mark-up required on the access price. Applying this to the proportion of sunk assets estimated to be used by the Pacific Bell local exchange,<sup>58</sup> he concluded a 135 per cent mark-up was required on the TELRIC-based access charge for use of links, and a 35 per cent mark-up was required on the TELRIC-based charge for use of ports.<sup>59</sup> This argument was subsequently rejected by the CPUC, which instead decided that the appropriate access price to set for the UNEs was given by using TELRIC, plus 19 per cent to recover shared and common costs.<sup>60</sup>

In Australia, the real options approach does not appear to have been presented yet in any formal submissions or proceedings relating to telecommunication access regulation. However, it would come as no surprise if such arguments were raised in the near future. Clearly, the problems of asymmetric risk and truncation both lend themselves to the application of real option theory.<sup>61</sup> For example, a paper by Ergas, Hornby, Little and Small (2001) presented at an ACCC Conference on *Regulation and Investment*, argues that a real options approach should be used to deal with the problem of regulatory risk. Further, the Commerce Commission (2001) in New Zealand has explicitly considered the potential for using real option theory, stating (at page 79, paragraph 357) that:

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<sup>56</sup> See *Reply affidavit of Jerry Hausman*, In the Matter of Implementation of Local Competition Provision in the Telecommunications Act of 1996, CC-Docket No.96-98, 30 May 1996.

<sup>57</sup> Holm (2000) makes the point that as the Dixit and Pindyck parameters have nothing to do with telecommunication investments, it is rather tenuous to try and claim that the data are appropriate for application to Pacific Bell.

<sup>58</sup> The estimates used by Hausman for the proportion of sunk costs were, 0.59 on links and 0.10 on ports.

<sup>59</sup> Alleman (1999) also established a significant mark-up in price is required. He outlines (at page 173) that if real option theory is not taken into account, standard TELRIC/TSLRIC models may underestimate the access price by as much as 60 per cent.

<sup>60</sup> The arguments put forward in his testimony were later more formally presented in Hausman (1999a).

<sup>61</sup> See Hausman and Myers (2002) for a recent paper that uses the argument of truncation for the application of real options in rail.



A second potential source of asymmetric risk is that the obligation to provide interconnection services removes the option for access providers to delay investment in their fixed PSTNs. If this option has a value, the costs of foregoing the option is a cost that should be reflected in interconnection prices.

#### 4.4.3 The Consequences of Below-Cost Access Rates

The consequences of having a below-cost rate for access to the ILECs' network elements and services are that there will be:

- regulatory takings;
- static allocative and production inefficiency; and
- dynamic inefficiency.

##### 4.4.3.1 *Regulatory Takings*

Sidak and Spulber have been leading proponents of the argument that the regulator, through its implementation of deregulation or unduly harsh regulations, can engage in some form of unconstitutional taking of property from the firm.<sup>62</sup> Property in this context refers not only to the physical assets, but also such intangible pecuniary property rights as the ability of the firm to earn an adequate return on its investment.

In assessing TELRIC/TSLRIC, Sidak and Spulber (1997a) have argued that by forcing the firm to set a price that is below cost, the regulator violates Section 252(d)(1) of the 1996 Telecommunications Act. This permits the regulated firm to recover costs by setting an access price that may include a reasonable profit. By guaranteeing that the firm makes a loss, TELRIC/TSLRIC is considered inherently confiscatory, and to constitute a form of takings by the regulator that is in breach of the Takings Clause of the Fifth Amendment of the US Constitution.

Although there is not the same protection afforded to intangible pecuniary property rights in the Australian Constitution, there does appear to be some concern about the issue of takings. For example, the PC (2001a) demonstrates its concern that FL costs may lead to 'regulatory takings' at pages 375-6, and outlines the arguments of Laffont and Tirole (2000) for dealing with the problem.

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<sup>62</sup> See Sidak and Spulber (1997a, b) for more detailed arguments about takings and the distinction between regulatory and deregulatory takings.

#### 4.4.3.2 Static Allocative and Productive Efficiency

Kahn (2001) has emphasised that one consequence of using the efficient costs of a hypothetical entrant is that the access price lies below the actual FL long-run-incremental cost of production that is faced by the firm. This leads to both allocative and production inefficiency.<sup>63</sup>

The regime clearly results in allocative inefficiency, because it induces “buyers to demand (incremental) quantities of the service in question, the value of which to them is less than the (incremental) costs that society actually incurs in providing them”.<sup>64</sup> Further, it fails to realise production efficiency because the correct cost target for any potential entrant to aim for is always the actual FL long-run marginal cost of production faced by existing firms in the industry. It would be considered unusual in practice for a potential entrant to decide that it must satisfy some hypothetically-efficient FL cost standard, rather than an actual FL cost standard, before it could enter an industry. Kahn (2001) highlights the issue of production efficiency when he states (at page 6) that actual FL cost-based prices,

...give challengers the proper target at which to shoot — the proper standard to meet or beat and the proper reward if they succeed. If they can achieve costs lower than that, firms will enter and in the process beat prices down to efficient levels. The FCC’s choice, of — omnisciently — prescribing at once what it thinks would be the *outcome* of such a process, *short-circuits* it...

#### 4.4.3.3 Dynamic Inefficiency

Most critics emphasise the potential for dynamic inefficiencies to arise as a result of the below-cost TELRIC/TSLRIC rates. There have been widespread predictions that the discounted prices will stifle future innovation and investment in the network, leading to socially-costly delays in the adoption of new technologies and services. For example in relation to setting substantially discounted prices for access Kahn et al. (at page 350) warn that:

The essential evil of such policies is that they discourage or delay the introduction of services that cannot be predicted beforehand. The cost to consumers can be enormous.

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<sup>63</sup> For similar arguments about the failure of TELRIC/TSLRIC to achieve allocative or production efficiency see Kahn et al. (1999).

<sup>64</sup> Kahn (2001) at page 4.

Kahn (2002) suggests that the below-cost rates for access to services and network elements bias and distort the efficient “buy or build” decision of potential entrants to the local telecommunications market. Instead of building their own local network, competitors are encouraged to enter the industry by reselling or leasing the ILECs’ services or elements. Ironically, regulations effectively discourage CLECs from engaging in exactly the type of facilities-based entry that the Act was originally designed to produce. Kahn reflects this view when he writes (at page 43) that in relation to TELRIC/TSLRIC:

...it is difficult to conceive of a standard more inherently contradictory of the Act’s manifest and understandable desire to encourage competitive challenges by entrants constructing their own facilities than their ability to obtain such facilities instead from the incumbent at prices at the lowest level that they could conceivably achieve themselves.

Crandall and Hausman provide a similar viewpoint when they state (at page 98) that the disincentive for entrants to invest in their own networks “is directly contrary to the goals of the 1996 Telecommunications Act”. They also claim (at page 100) that if competitors in the US were not able to lease local networks and resell local services on such favourable terms, “new entrants would undoubtedly have moved more quickly to build their own networks, mobilizing even more capital and converting it into modern network facilities”.

Aside from the adverse impact upon the investment behaviour of entrants, below-cost prices have detrimental effects on the future investments made by the access provider. By failing to provide the incumbent with an adequate return on its assets, the regulation deters the access provider from undertaking innovation, and upgrading or enhancing its existing facilities. Crandall and Hausman highlight this disincentive in the following passage (at pages 86-7).

Incumbents are less likely to invest in innovative services or facilities if their future returns are truncated by the prospect of having to lease such facilities to their rivals at below-cost prices.

They then proceed to make the more extreme claim that the discounted rates set by the FCC could induce the incumbent simply to allow the existing network to atrophy, or not to invest at all.

In Australia, the PC (2001a) and PC (2001b) have highlighted similar claims made by Telstra about the adverse impact TELRIC/TSLRIC has on investment. PC (2001a), cites (at page 399-400) a passage from Telstra where the firm claims that in relation to the PSTN:

By consistently enforcing access prices for declared services that are significantly below cost, the ACCC reduces the incentives that Telstra has to continue to invest in its network and that Telstra's competitors have to invest in alternative network infrastructure.

PC (2001b) also cites a passage (at page 78) where Telstra suggests:

Unless the [telecommunications] regulatory environment is changed so as to significantly reduce its distorting impacts, it is difficult to see any commercial incentive for Telstra to incur the substantial outlays involved in upgrading the [Customer Access Network]

Forecasts of under-investment in the local network and imminent bankruptcy have become standard in the criticisms of the regulatory regime used by the FCC and ACCC. Kahn et al. (at page 349) perhaps best summarise the perceived inadequacies of TELRIC/TSLRIC regulation for stimulating investment when they state that:

It would be difficult to imagine an arrangement more hostile to the risky and costly investment in modern telecommunications infrastructure and the development of the new products and services that it makes possible.

## 4.5 Assessing Criticisms and Myths of TELRIC/TSLRIC Access Prices

This Section questions some of the criticisms of TELRIC/TSLRIC-based access charges outlined in Section 4.4. In particular, it examines the:

- first-mover advantage experienced by the investor;
- similar information required for price-cap and TELRIC/TSLRIC regulation;
- debate over costs used to estimate TELRIC/TSLRIC prices;
- similarities that Schumpeterian, access holiday, takings and real option arguments have to the controversial Efficient Component-Pricing Rule (ECPR); and
- applicability of real option theory, and the appropriate method that should be used to take real options into account in the telecommunications industry.

### 4.5.1 The First-Mover Advantage

While incumbent network access providers have readily complained about the level of regulated access price and need for some form of patent protection — e.g. the access holiday proposed in Australia — they have generally been reticent in acknowledging the significant advantage bestowed upon them from being an established firm in the market. The empirical evidence from the US outlined in Section 4.6 about the relative market shares of ILECs and competitors, suggests that there may be a significant first-mover advantage in the local exchange market. The impact of this is that it may outweigh any adverse impact that regulation is alleged to have. Noam (2002) highlights that a first-mover advantage may exist in telecommunications, when observing (at page 418) that:

In most countries, even after a number of years of competitive entry, the incumbent still is dominant in most traditional market segments.

ACCC (2001) has recognised this potential for a first-mover advantage in telecommunications, when responding to the Productivity Commission's proposal for an access holiday. The ACCC outlines (at page 18) that it is concerned about the "significant market power derived from the first-mover advantages an incumbent enjoys when it is protected from competition in the early years of a new product." The regulator maintains that the ability of the incumbent to establish a customer base means that the "access seekers can be at a competitive disadvantage, as it must be more

efficient than the access provider by at least the churn transaction costs if it is to win a customer over to its business”.

Cave and Williamson (1996) highlight the problems entrants have in breaking into an established market in any industry. They point out that on average 75 per cent of new entrants in industries fail within the first two years, and only 15 per cent survive beyond five years. Generally speaking entrants suffer from the disadvantage that they do not have a well-established brand name, lack experience in the marketplace, and have a far smaller amount of capital assets than the incumbent. The initial success of an entrant relies upon it being able to offer a new service that uses assets embodying the latest technology, which cannot be easily replicated by the incumbent. By subjecting the incumbent to such an “innovation gap”, the entrant has a chance to make up ground on the “asset accumulation gap” it faces. Cave and Williamson refer to this attempt by entrants to establish a presence in the industry as a “race for survival”.

In relation to the telecommunications industry, Economides (1999) notes that there appears to be a first-mover advantage, as it has been established that many large commercial buyers are willing to pay more for services offered by an integrated operator than for resold services. According to Armstrong (1997), in addition to the barriers to entry created by sunk costs and capacity constraints, in the telecommunications industry a significant barrier is created by the prevalence of customer inertia. He suggests that this may be offset if the regulator allows for number portability and equal access. However, Holm (2000) observes that, even when switching costs are low — due to such regulations as local number portability — consumers are still reluctant to change operators, unless there are substantial discounts offered by the new entrants.

#### 4.5.2 Similar Information Problems to Price-Cap Regulation

Critics have highlighted the problems of estimating efficient FL costs, yet they have been quick to extol the virtues of price-cap regulation. In practice, this ignores the fact that price-cap regulation encounters very similar information problems when it attempts to set an appropriate ‘X’ factor for a period of usually three or four years. As Laffont and Tirole (2000) point out, in the telecommunications industry one of the major considerations for determining the X factor in the price cap is the forecast rate of technological progress. Therefore, similar to TELRIC/TSLRIC, PC regulation requires the regulator to make some judgement about how costs will evolve in the future.

However, the need for this sort of information under price-cap regulation has not received anywhere near the same level of scrutiny or criticism as it faced under TELRIC/TSLRIC regulation.

#### 4.5.3 The Cost Debate

##### 4.5.3.1 *The Myth of a Hypothetical Efficient Local Network*

A common criticism of TELRIC/TSLRIC has been that, because it assumes the market is perfectly contestable, the model simply estimates the costs of reconstructing a virtual or hypothetical local network embodying the best-available technology. Such an assessment and summary of the re-optimisation process is misleading and unfounded. In practice the re-optimisation that the regulator employs on the network is far from virtual or hypothetical. As Ergas (1998) and the PC (2001a) point out, key components of the incumbent's existing network are held constant, by using:

- a scorched-node approach to regulation, rather than a scorched-earth approach; and
- the best-in-use technology, rather than the best-available technology.

As outlined earlier, the **scorched-node** approach estimates the efficient FL costs of the network by holding the location of the existing local switching nodes of a network fixed. This is in contrast to the scorched-earth approach to regulation, which allows the location of the nodes to vary, and be placed wherever the regulator deems to be most efficient. The scorched-earth approach provides the regulator with far more discretion than the scorched-node approach, as the network design under a scorched-earth approach may bear only a passing resemblance to the incumbent's existing network. In comparing the two methods, the PC (2001a) notes (at page 398) that the "scorched node approach generates higher access prices than the alternative."

The assumptions the regulator makes about technology are also essential for determining whether it is reasonable to label the network used for cost estimation as hypothetical. As outlined earlier, it appears there are two options the regulator can adopt — the "best-available" technology or the "**best-in-use**" technology.

The best-available technology requires the regulator to judge what, amongst a set of new technologies, would be best for an incumbent to deploy in its network. In the extreme case it makes it possible for the regulator to estimate the costs of the network using a completely new technology that has not actually been adopted by any access provider. Such a calculation would require an extraordinary level of detail, and the

judgements about the best technology have the potential to be rather arbitrary. This is particularly the case for an industry like telecommunications where there is currently such a rapid rate of technological progress. The methodology implicitly relies on the regulator being able to “pick winners”, as there is potential for the technology chosen to have no long-term future in servicing the local market.

Best-in-use technology requires far less regulatory discretion, estimation and uncertainty. The calculations are less formidable, as it uses the most efficient technology that is commercially available and compatible with the existing network design. The price is generally estimated by using the replacement costs of the technology that has already been deployed in the network by the incumbent. The network closely resembles that of the incumbent, and any difference in the cost estimates between the regulator and incumbent could merely reflect cost inefficiencies or a deliberate over-statement of costs. Even though some assessments of TELRIC/TSLRIC describe it as incorporating “best-available” technology, in practice it appears regulators commonly assume the network employs best-in-use technology.

The combination of a scorched-node approach along with best-in-use technology means that, in practice, regulators attempt to estimate the actual FL costs of the firm, which Kahn et al. assess, provides the correct signals for overall market efficiency. In Australia, this is highlighted by the ACCC (2001) which outlines (at page 23) that when employing the best-in-use technology to calculate the FL costs of the PSTN access services provided by Telstra, its approach “incorporates a number of parameters based on actual costs (as provided by Telstra), rather than ‘efficient values’”. The PC (2001a) cites this passage at page 399, and further points out that estimates “of forward looking trench and cable lengths were largely based on Telstra’s estimates, while the...access deficit contribution made by PSTN access services were based on Telstra’s actual costs.” Hence, it could be argued that those who describe the regulated network as a fantasy, virtual, or hypothetical network, are criticising a regime that has little to do with the TELRIC/TSLRIC regulation that has been used in practice. Instead, they envisage the most extreme and unfavourable application of TELRIC/TSLRIC to the access provider, and by doing so evaluate what can only be described as a virtual, fantasy or hypothetical form of regulation.



#### 4.5.3.2 *Cost Confusion between the US and Australia — Actual BL or FL costs?*

In evaluating TELRIC/TSLRIC, commentators such as Kahn et al. have recognised the incentive problems and inefficiencies associated with BL/historical/embedded cost regulation that led to its rejection in the US. As already outlined in Section 4.2, they state (at page 324) that there is “widespread agreement” amongst economists about the need for FL cost regulation in setting the access price. In opposing what they claim is the hypothetically-efficient FL cost standard used by the regulator, critics such as Kahn et al. and Weisman, have argued for prices based on the actual FL costs of the firm. Other critics of the hypothetical efficient FL cost standard have been less precise in describing the alternative regime that should be adopted, and have only advocated the use of actual costs by the regulator. The recent analysis by Noam (2002), that briefly summarises the cost debate in the US, suggests (at page 408) that these references to actual cost are intended to mean actual FL costs.

In Australia, when the Productivity Commission deals with the issue of regulatory asset valuation in PC (2001b) Chapter 13, it clearly characterises the debate as being between the use of the FL costs and BL costs, and unlike the US, does not draw any distinction between types of FL cost regulation. For example, it states (at page 356) that:

While there are a multitude of asset valuation methods, debate between access seekers, infrastructure owners and policy makers tends to focus on whether an historical cost approach (often termed depreciated actual cost — DAC), or a replacement cost methodology, is more appropriate. The most common replacement cost methodology used in Australia is the depreciated optimised replacement cost (DORC or ORDC).

The analysis by the PC may either suggest that:

- the Productivity Commission has misunderstood the cost debate. There is evidence of this, as when comparing utility regulation in the US and Australia, it claims (at page 357) that “in the USA, historical cost valuation methods are used almost exclusively”; or
- in Australia, the DAC method, which has been labelled a BL cost method, is in practice what has been described in the US as a actual FL cost method, while DORC is an example of a hypothetical efficient FL cost estimate. This seems possible given that the DAC technique uses costs which have been depreciated, so that the asset reflects current values, and costs that are sometimes also optimised; or

- as opposed to the US, there has not been quite the same “widespread agreement” in Australia about the use of FL costs, and the alternative regulatory regime advocated is based on actual BL/historical/embedded costs.

As criticisms of the Australian access regime often mimic those raised in the US, if the last outcome were true, it would imply that those parties advocating the use of “actual cost” regulation in Australian telecommunications, have simply repeated US arguments without closely scrutinising the context in which the term “actual cost” was used.<sup>65</sup>

While the case against BL cost regulation is well established, there has been some recent theoretical work by economists in New Zealand on access pricing and investment — Guthrie, Small and Wright (2001) and Evans and Guthrie (2002) — supporting the adoption of BL costs by the regulator. These papers compare investment timing and welfare under BL and FL cost-based access prices, using a model that assumes there is no incentive for the firm to cost pad. Both conclude that, in this setting, BL cost regulation leads to earlier investment and greater benefit to society in industries such as telecommunications, which experience rapidly decreasing costs over time. These papers are looked at in greater detail in Chapter 5.

#### 4.5.3.3 *FL Cost Regulation can Benefit the Incumbent*

In contrast to arguments made about under-pricing of access, Holm (2000) asserts that access prices based upon FL costs of the local exchange markets may result in a higher access charge. Using empirical evidence provided by OVUM (1998) on the Danish telecommunications industry, Holm points out that, while the FL cost of constructing most parts of the telecommunications network have decreased, the FL cost of constructing the local access network has actually increased. The FL cost estimates provided by OVUM for the existing local access network of Tele Danmark in 1996, which appear to be based on a scorched-earth approach, were four to five times higher than the historical book value of the asset. Holm provides two reasons for this outcome:

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<sup>65</sup> There is evidence to suggest that criticisms from the US have been repeated in Australia, even though they may not be appropriate for the Australian market. For example, in claims made by Telstra and NECG about under-pricing, both parties treat Telstra as if it is like the vertically-separated access provider in the US local telecommunications market. Their arguments ignore that in Australia, Telstra is in fact a vertically-integrated telecommunications service provider, which appears to have some level of dominance in the downstream market. The PC (2001a) recognise this problem with the Telstra and NECG arguments, when it outlines (at page 396) that such claims about the adverse consequences of below-cost rates, “have been rooted in a world in which there is no downstream market power”.

- (1) the existing access network had already been substantially depreciated; and
- (2) as opposed to the core network, the existing local access network had become more costly to build over time.

The first reason suggests that the incumbent will receive an unaccounted capital gain as the value of the existing asset is increasing, but this is not being adjusted for in the regulatory depreciation schedule.<sup>66</sup> The second of the reasons suggests that at the time, the local market was still subject to strong natural monopoly conditions.

Based upon the OVUM data, the FL cost-based access price set by the Danish regulator would have been higher than BL cost-based access price, and this shows the potential for FL cost regulation to be beneficial to the network access provider. It has led Holm to query whether or not:

...politicians are fully aware of this fact when they argue so strongly in favour of using LR(A)IC [long run (average) incremental costs] for determining the price of ULLs (unbundled local loops) as well.<sup>67</sup>

#### 4.5.4 Schumpeterian Arguments, Access Holidays, Takings and Real Option Theory — Parallels with the Efficient Component-Pricing Rule (ECPR)

The Efficient Component-Pricing Rule (ECPR), also known as the Baumol-Willig (BW) Rule — in recognition of those responsible for its formulation — has been recommended as an efficient means for pricing access to an upstream facility of a vertically-integrated monopoly. Baumol and Sidak (1994) summarise (at page 178) that the ECPR involves an access price where:

$$\begin{aligned} \text{optimal input price} = & \text{the input's direct per-unit incremental cost} + \\ & \text{the opportunity cost to the input supplier of} \quad (4.5.1) \\ & \text{the sale of a unit of input} \end{aligned}$$

Baumol and Sidak (1994, 1995) highlight that this access-pricing rule is production efficient as an entrant only seeks access to the network if its long-run marginal cost of supplying the downstream market is lower than that of the vertically-integrated incumbent. Further, if prior to entry occurring, the vertically-integrated monopoly sets the retail price above long-run marginal cost to cover some existing shared or common

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<sup>66</sup> The model used in Chapter 5 capture this type of outcome in Section 5.3.

<sup>67</sup> Holm (2000) at page 98.

cost or universal service obligation, then as Armstrong, Doyle and Vickers (1996) and Armstrong (2002) show, the ECPR yields a second-best efficient or Ramsey-Boiteux access-pricing regime. However, the problem with ECPR is that, as critics such as Tye (1994) note, it has the potential to sustain significant levels of allocative inefficiency. The reason for this is that in the extreme case where the vertically-integrated monopoly originally earns monopoly profits, the second part of the pricing rule will reclassify the lost monopoly profits as an opportunity cost associated with deregulation and entry.<sup>68</sup> This potential for the ECPR to embed the monopoly profits of the incumbent by categorising them as a cost of production has led regulators in various countries — including Australia, New Zealand, the UK and US — explicitly to reject the ECPR.

#### *4.5.4.1 Schumpeterian and Access Holiday Arguments*

Schumpeterian and access holiday arguments make explicit that, by not allowing the firm the reward of monopoly profits when socially-beneficial innovations are made, the regulator fails to take into account dynamic efficiency and the social opportunity cost of R&D. There may be some legitimacy to the Schumpeterian and access holiday arguments, however it is apparent that they explicitly advocate the need for the incumbent to maintain the type of rents that the ECPR has been criticised by Tye for attempting to retain.

#### *4.5.4.2 Stranded Costs and Takings*

Stranded costs first became a topical issue in the US in the early 1990s. While there is no precise definition for the term stranded cost, it appears to have been loosely defined as those losses or costs incurred by the regulated firm as a result of the increased competition arising from deregulation. The issue appears to have been most prominent in the US electricity industry, where the value of many vertically-integrated generator firms was adversely affected by deregulation. Numerous academics such as Baumol, Sidak and Spulber,<sup>69</sup> argued that the stranded cost, or decrease in firm value,

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<sup>68</sup> It is interesting to note that this is not the first time Baumol has been responsible for redefining cost concepts. For example Baumol and Willig (1981) (at page 406) redefine the term “fixed costs” to mean “costs that are fixed in the long run as well as in the short”. Consequently, according to the authors, such things as large-scale plant and equipment, no longer qualifies as a fixed cost of production. This has led to some confused discussions in utility pricing, where authors use the term fixed cost, yet interchange its meaning between the conventional short-run fixed cost and the long-run “Baumol” fixed cost.

<sup>69</sup> For example see Sidak and Spulber (1997) and Baumol (2000).

represented a ‘takings’ by the regulator.<sup>70</sup> They asserted that, prior to deregulation, an implicit ‘regulatory contract’ — a regulatory compact — existed between the regulator and firm. That is, in return for forcing the utility to bear certain costs, the regulator guaranteed the firm it would be able to earn a given rate of return. By allowing competition, the regulator breached this regulatory compact, and the resulting decrease in value constituted a taking that should be compensated by the regulator.<sup>71</sup>

The issue of takings may be a legitimate problem in regulated industries. This is the case for instance if the regulator acts opportunistically and sets a price that jeopardises the long-term future of an efficient firm.<sup>72</sup> However, a problem with the takings arguments is that, as with the ECPR, it can be manipulated to reclassify lost rents as an opportunity cost. For example, if prior to deregulation and entry occurring the incumbent earned monopoly profits, following the takings argument through logically, these profits would now be considered a “stranded cost”.

#### 4.5.4.3 *The Real Option to Wait*

The argument that was originally made by Hausman for the introduction of real option theory in telecommunications was that, TELRIC/TSLRIC regulation destroyed the opportunity for the incumbent to delay the uncertain and sunk investment in the network.<sup>73</sup> This imposed an additional opportunity cost upon the firm which advocates of the real options approach suggested should be compensated for by providing a mark-up on the allowed access price. The problem with this argument is that it relies on the firm being able to choose when the most appropriate time is to invest in the future. This ability only arises if originally the firm has some market power. Therefore, the claim that regulation destroys an “option to wait” effectively requires the incumbent to be compensated for the lost rents that accompany deregulation and competitive entry. Like

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<sup>70</sup> The example here is of a deregulatory taking, as opposed to a regulatory taking.

<sup>71</sup> For analysis that highlights the problem of compensation in the presence of stranded costs without using any takings argument, see Kolbe, Tye and Myers (1992) and Kolbe and Tye (1995).

<sup>72</sup> An example of this type of regulator taking is highlighted in the model used in Chapter 5.

<sup>73</sup> There appears to have been three arguments used for incorporating real options in the access price. That is: (a) regulation has destroyed the investor’s option to wait; (b) TELRIC/TSLRIC is based on a perfectly-contestable market outcome; and (c) asymmetric risk arises from regulation due to the truncation problem. It is argument (a) that is shown here to be subject to the same flaws as the ECPR. In fact, of these arguments, only argument (c) appears to have any merit, and it appears to have recently been used by Hausman and Myers (2002).

the ECPR, real option theory has the potential to redefine lost rents as a cost of regulation and competition. Jamison (1999) uses a simple model to provide a formal proof highlighting the link between the ECPR and real options approach

#### 4.5.5 Real Option Theory and Telecommunications Regulation

Aside from the problem that real option theory may be used in the same way as the ECPR, there are also questions about whether real option theory should be applied to the regulation of telecommunications? And if it is applicable, how it should be applied?

##### 4.5.5.1 *The Applicability of Real Option Theory to Telecommunications*

Economides (1999) questions the applicability of real option theory to telecommunications by arguing that there may no longer be the requisite degree of uncertainty and irreversibility to justify adopting such an approach. He claims that:

- most investments that are uncertain now have significant resale value, and
- many of the investments considered sunk, were generally not the subject of any great deal of uncertainty.

For example, Economides points out that:

- switches in networks can now be moved to new locations and used elsewhere;
- the local loop may be used to provide alternative services such as xDSL;
- end-office real estate can be sold; and
- there is no significant uncertainty in relation to the local loop, because competing local exchange carriers (CLECs) will purchase it.

Further, Economides suggests (at pages 211-2) that, even if there was the necessary level of uncertainty and sunk costs for real option theory to be applied, in the oligopolistic environment of the local US telecommunications market, the incumbent would no longer be able to afford to wait. Hence, the value to an incumbent local exchange carrier of waiting to invest when it anticipates there is likely to be strong competition in the future could well be negative.

Mason and Weeds (2001) have established a model that explores this idea that there is a trade-off between the strategic incentive to pre-empt the investment, and the impact of uncertainty and irreversibility. They find that the incentive pre-empt has the potential to decrease or even eliminate the option that arises due to uncertainty and irreversibility.

#### 4.5.5.2 *Taking into Account the Call and Put Option in Telecommunications*

Aside from the call option to delay the investment, there has been a growing recognition in real option theory that investors have an option that will arise after the investment has occurred, similar to an American put option. Abel, Dixit, Eberly and Pindyck (ADEP, 1996) adopt this approach, arguing that, by making the initial investment, the firm is able to provide itself with increased future flexibility and additional investment opportunities. This provides the firm with a benefit that has the potential to offset any increase in cost arising from removing the call option to delay the investment. If this put option has significant value relative to the call option, a real option approach may then conclude that the investment should occur even though the standard neoclassical investment net present value is less than zero.

Hubbard and Lehr (1999), apply the ADEP model to the telecommunications industry, and argue that:

- the call option to delay the investment is less valuable in the current environment of the telecommunications industry; and
- put options arise due to the additional growth opportunities and strategic flexibility once the initial investment is made.

Hubbard and Lehr outline that the Internet, rapid technological advancement and the changes in industry structure have complicated the issue of how to account for real options in telecommunications. They argue that it is possible for the value of the call option to defer the investment to increase or decrease taking into account these considerations. Further, there is the emergence of a significant put option, which arises from the increased growth opportunities and strategic flexibility the firm now has, once the investment has been made. This means that any new investment undertaken by the firm may be considered as providing it with a crucial starting point from which it can make a far more complex sequence or chain of investments. Consequently, contrary to the arguments of Hausman (1999a), the original investment may not actually narrow the opportunities available to the firm, but increase them. For example, the development of xDSL technology has meant that the value of the original investment — the copper wire infrastructure — has increased, and this has had the effect of enhancing the reversibility of this asset and increasing the size of the put option. If the size of the put option were

large relative to the size of the call option, then the application of real option theory would require an access price set lower than the TELRIC/TSLRIC-based charge.<sup>74</sup>

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<sup>74</sup> For further details on the applicability of real option theory to telecommunications and how real option theory should be applied, see the book titled *The New Investment Theory of Real Options and its Implications for Telecommunications Economics* or Funston (2001).



## 4.6 Evidence of Trends in US and Australian Telecommunications

This Section looks at whether there is any substance in criticisms of the TELRIC/TSLRIC access-pricing regime, and claims that it under-prices access and has an adverse impact upon investment. To do this, trends are assessed in the access price and level of investment for the US local telecommunications market and Australian PSTN services.

### 4.6.1 Evidence from the US Local Telecommunications Market

To evaluate the success of the TELRIC-based charges used to price access to the local-exchange market in the US, it is necessary to examine pricing (both access and downstream retail), competitive entry and investment outcomes in the local telecommunications market, since the introduction of the 1996 Telecommunications Act. The data presented here have been selected from numerous papers, most of which use information that was originally provided by the FCC in 2000 and 2001.

#### 4.6.1.1 *Telecommunications Pricing*

Critics of the TELRIC/TSLRIC model highlight the wide divergence in the FL cost-based access prices estimated across different states. Crandall and Hausman (2000) outline that, in downtown Chicago an entrant could lease a line for less than US\$5 per month, while in Denver, a similar line with almost identical technology, costs more than US\$25 per month. Although some price variation would be anticipated due to the different market conditions across the various states, they assert (at page 97) that “no ‘cost model’, however imprecise, guides these results.” Similarly, Noam (2002) outlines that access prices for the local loop ranged from US\$3 in one state, to almost US\$30 in another. Crandall and Hausman (2000) and Crandall and Hazlett (2001), both attribute this inconsistency in the application of the FCC methodology to the political process of rate setting. Crandall and Hausman describe TELRIC/TSLRIC (at page 98) as being “a political process wrapped in the guise of efficient regulation”.

The arguments raised by incumbent firms only appear to consider consumers to the extent that they incur welfare losses if the regulator fails to provide proper incentives for socially-beneficial investments in new technology. The benefits derived by consumers due to the increased retail-market competition resulting from the FCC’s regulation are often ignored. In some areas where long-distance companies have entered the local

market, the price decreases and increases in services have been significant. For example, just four months after AT&T entered the Michigan market, the incumbent local carrier SBC cut retail prices on many of its local packages to customers by as much as 30 per cent.<sup>75</sup>

#### 4.6.1.2 *Competitive Entry to the Local Market*

Even with the advent of competition in the local telecommunication market, Woroch (2002) outlines that by the end of 1999 the four RBOCs together owned 88 per cent of U.S. end-user lines, with Verizon and SBC accounting for nearly two-thirds of this ownership. In addition, RBOCs still collected 94 per cent of the ILEC end-user revenues. The President of MCI Mass Markets, Wayne E. Huyard, has suggested that even where the RBOCs have lost local lines, this is largely due to customers dropping their landline services altogether and moving to wireless companies still owned by the incumbent.<sup>76</sup>

The data suggests that RBOCs have not been adversely affected by the use of FL cost regulation. Although these firms appear to still dominate the industry, CLECs have made gradual inroads into the local market.<sup>77</sup> Since the introduction of the Telecommunications Act, 165 new phone companies have emerged, and the combined market share of competitors has increased strongly in terms of access lines and revenues.<sup>78</sup> In the last quarter of 1997, CLECs provided just above 1 per cent of the nation's fixed access lines. By the close of 2000, Woroch (2002) shows that this figure had increased to 8.5 per cent, as CLECs provided 16.4 million of the nation's 193.8 million fixed lines. Of these, 7.75 million lines were owned by CLECs, the remaining two-thirds obtained from ILECs as UNEs or resold loops. Woroch also points out that, in 1999, CLECs had US\$6.5 billion of sales, and had a cumulative average growth rate exceeding 87 per cent over the proceeding 8-year period.

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<sup>75</sup> "FCC Plans to Erase a Key Rule Aiding Local Phone Competition" by Yochi J. Dreazan and Shawn Young, *The Wall Street Journal*, 6 January 2003.

<sup>76</sup> "Letters to the Editor: The Bells are Clamoring 'Crisis' — But Don't Listen" by Wayne E. Huyard, *The Wall Street Journal*, 30 December 2002.

<sup>77</sup> Spulber (2002) outlines (at page 497) that although the market share of CLECs remains small, their geographical reach has widened to such an extent that CLECs are almost ubiquitous.

<sup>78</sup> Crandall and Hazlett (2001) at page 25.

Even with the recent evidence that competition is gradually increasing in the local market, detractors have been quick to point out that the growth in competition pales in comparison with the levels experienced in the long-distance market. In particular they point to the slow growth in facilities-based entry. Such assessments though appear to be unduly harsh.

Comparing the growth of competition in long-distance and local markets is similar to comparing “apples with oranges”. The long-distance market has been subject to competition for around 30 years, with the successful entry of MCI in the 1970s. Competition has since evolved rapidly, aided by advances in technology and the handing down of the MFJ. In contrast, competition was only allowed in the core areas of the local telecommunications market after the introduction of the 1996 Telecommunications Act. Further, the costs of entry into the local telecommunications markets have not decreased in the same manner as they did in the long-distance markets. As Woroch (2002) points out, the scale and scope economies of the local network have not vanished. A study by the Chicago research company New Paradigm Resources Group Inc established that it could cost as much as US\$100 million to outfit a large city with voice switches for a new local network.<sup>79</sup>

Using FCC data on facilities-based entry from the middle of 1999, Crandall and Hausman estimate that of the total lines in the US local telecommunications market, only 1.1 per cent were being provided by the entrants’ own facilities. They comment (at page 93) that:

Surely this is a paltry result more than three years after the opening of the market to competitive entry, particularly when the competitive access providers had already built a substantial share of these lines before the passage of the 1996 law.

The authors though neglect that, as a percentage of the total number of lines actually being provided by competitors in mid-1999, facilities-based services constituted approximately 30.6 per cent of the lines provided by competitors. Alternatively, this can be restated as saying that in mid-1999 just under one-in-three entrants to the local telecommunications industry chose to enter by constructing their own facilities. From the more recent FCC data outlined above, it is also evident that this number has steadily

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<sup>79</sup> “The Economy: Shine May Return to Bells — FCC Could Heed Clamor Over Competitors’ Access to Networks” by Shawn Young and Dennis K. Berman, *The Wall Street Journal*, 7 January 2003.

increased. In this light, the level of facilities-based entry does not appear quite so insignificant.

Crandall and Hausman admit that there has been a slow take-up in leasing UNEs. In 1999 in all but five states of the US leased local loops comprised less than 1 per cent of switched access lines. Combined with the data on facilities-based entry, this appears to contradict claims that the FCC's FL cost regulation leads to network elements being under-priced and to a substantial bias in the "buy or build" decision towards entry by the lease of UNEs. However, Crandall and Hausman write (at page 93) that, while the result is "surprising in view of the low wholesale rates established", the reason for this lack of interest is,

... undoubtedly that the entrants have been waiting for an even more attractive regulatory option — the entire bundle of network facilities in a (reconstituted) bundled network facilities at regulated prices that are well below the resale rate.

To support this they provide evidence that, after Bell Atlantic offered the entire wholesale platform in New York, the number of leased local loops rose from 49 000 at the end of 1998 to 138 000 in June 1999. More recently, Woroch (2002) has noted that during 2000, the use of leased UNE loops nearly doubled. However, before reaching any conclusions based on these figures, it is important to recognise that there have been similar trends with resold lines, and as an overall percentage of competitive entry, facilities-based competition is still increasing.

Using more recent FCC data than Crandall and Hausman, Crandall and Hazlett (2001) are more reserved in their criticism of the access-pricing regime. They still claim TELRIC/TSLRIC is an asymmetric form of regulation favouring entrants, but concede that it has been successful in increasing competition in the local market. As with the analysis of Crandall and Hausman though, they suggest that there is still a lack of facilities-based competition. Examining a sample of CLEC stocks in 2000, they note (at page 27) that:

It is also of interest that the star performer in the CLEC group was Winstar, a wireless firm able to offer facilities-based competition as opposed to service over leased portions of incumbent's networks.

Ironically, Winstar Communications Inc. has since failed, and is now being used by CLECs as an example that highlights the difficulties of successfully engaging in

facilities-based entry and competition in the local market. As an AT&T representative recently noted:<sup>80</sup>

The CLECs tried the ‘build it and they will come’ approach, and those companies are now bankrupt.

#### 4.6.1.3 *Investment in the US Local Telecommunications Market*

In assessing investment, like many others, Crandall and Hausman recognise (at page 108) that it is

...too early to estimate the effects of the regulatory climate on investment strategies in any detail.

This does not stop them in the very next sentence from stating that,

A brief look at recent investment trends suggests, however, that regulation may be a substantial drag on investment in the traditional telephone industry.

Crandall and Hausman substantiate this claim by showing that, amongst other things:

- investment levels have been higher in the totally-deregulated wireless market and the partially-deregulated long-distance market, than in the fully-regulated local telecommunications market;
- that, despite the large potential market for new broadband services, there has only been a modest increase in capital spending; and
- that in 1998 ILECs’ investment in the deployment of DSL technology increased only very marginally.

Although Crandall and Hausman attribute the above results to over-regulation and the under-pricing of access, each of these outcomes is also symptomatic of the ILECs still having some type of market power.

As it has already been shown, there appear to be significant barriers to entry in the local telecommunications market due to sunk costs,<sup>81</sup> scale and scope economies and substantial customer inertia. Even with the successful entry of CLECs it has been

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<sup>80</sup> “FCC Plans to Erase a Key Rule Aiding Local Phone Competition” by Yochi J. Dreazan and Shawn Young, *The Wall Street Journal*, 6 January 2003.

<sup>81</sup> Spulber (2002) suggests (at page 497) that the argument that sunk costs create a significant barrier to entry into the local exchange are “rendered moot by the substantial entry into local telecommunications that began before the 1996 Act and has continued afterwards.”

evident that incumbent firms have maintained large shares of the market. RBOCs end-line user revenues have only been modestly affected by entry, and despite claims of imminent bankruptcy due to the FCC's FL cost regulation, in 2002 the former Regional Bell, SBC, still made an operating profit of more than US\$2 billion.<sup>82</sup>

Rather than indicating under-pricing and over-regulation in the local-exchange market, the higher levels of investment in the wireless and long-distance markets may be attributed to greater competition arising in these industries. It is well established that there is less competition in the local telecommunications market than both the long-distance and wireless markets. This is evidenced by Crandall and Hausman, who, when comparing the regulated local telecommunications market with other deregulated markets, state (at page 110) that:

By contrast, competition in the totally deregulated wireless market is flourishing, and competition in the partially deregulated long-distance market has increased...

Aside from the quantity of investment being less, when a firm has market power, the investment-timing model used in Chapter 6, shows that there is also an incentive to delay the investment relative to a competitive investor. Hence, the failure of an ILEC to undertake socially-beneficial investments in new technology — such as broadband or DSL — appears consistent with it still having some market power.

The idea that increased competition in the local-exchange market should stimulate more investment than it deters is indicated by the results of an econometric study undertaken by Woroch in 2000, summarised in Woroch (2002). Examining 1984-1992 data, when there was only limited competition in local telecommunications, he finds that “entry triggers ILEC investment”.<sup>83</sup>

#### 4.6.2 Evidence from the Australian PSTN Services

A BIS Shrapnel (2001) report highlights (at page 28) that the copper PSTN network of the vertically-integrated telecommunications provider Telstra, covered “more than 99.75% of the Australian population in the six states and two territories”. To examine

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<sup>82</sup> “Companies and Finance the Americas — Untangling the wires for Baby Bells” by Peter Thal Larsen, *Financial Times*, 7 January 2003.

<sup>83</sup> Woroch (2002) at page 698.

the impact TSLRIC-based access prices have had on the levels of investment in the PSTN copper network by the vertically-integrated service provider Telstra, data and assessments of the access regime provided by the Productivity Commission — in Chapter 11 of PC (2001a) — are outlined here.

#### *4.6.2.1 Access Prices for PSTN services*

In 2000-2001, the ACCC (2000a) estimate (at page 24, Table 7.5) that the national (weighted average) TSLRIC++ access price for PSTN services is 1.53 cents per minute, of which the access deficit contribution (ADC) comprises 0.69 cents per minute of the charge. The Productivity Commission recognise the potential for the TSLRIC-based access price to affect the level of investment when in PC (2001a) it states (at page 364) that:

High access prices will entrench the incumbent, frustrate investment in downstream facilities, encourage inefficient bypass and raise consumer prices. Low access prices will bias the build-buy decisions of competitors, encourage too much downstream investment and frustrate investment in the core infrastructure...

In assessing TSLRIC, PC (2001a) outlines (at page 363, Box 11.1) that it “considers there are some problems in the ACCC’s methodology for calculating TSLRIC prices for PSTN services. It highlights the uncertainty associated with TSLRIC estimates and the risk of regulatory error and notes its concern (at page 398) that “some cost components of the TSLRIC for the domestic PSTN may be underestimated”. While it suggests this may be offset by other cost factors that are over-estimated, it concludes that, in the long run “it is sceptical that...underestimated cost elements...are offset by overestimated cost elements”.

Although the Productivity Commission indicates that the ACCC may under-estimate access prices, it does not make any conclusive remarks that it is occurring. The problem with making any definitive judgements is that, unlike access providers in the US local telecommunications market, Telstra is vertically-integrated service provider that appears to dominate the downstream market. Consequently, the Productivity Commission observes that, any adverse consequences from having an access price set too low, are at present, likely to be offset by the downstream market power held by Telstra. The PC (2001a) states (at page 396):

To the extent that the incumbent can still earn monopoly rents on the regulated services — through its downstream market power — this

suggests that the regulated TSLRIC access price is not too low (in the sense of distorting the incumbent's investment incentives in the bottleneck facilities).

and acknowledges (at page 398) that a downstream monopoly “provides a buffer for the effects of access pricing on investment”.

In highlighting the downstream market power of the incumbent, the Productivity Commission outlines (at page 396), “Telstra notes that fixed line telephony has been more profitable than its non-telephony services”, and that the ACCC (2001) has estimated (at page 29, Box 3.1) that the PSTN provides Telstra with economic rent (i.e. above normal returns) of \$1800 million.<sup>84</sup> While the Productivity Commission queries the assumptions that the ACCC used to estimate this surplus, it concedes (at page 397) that, “a significant error — of more than 30 per cent — would be required for the measured surplus to vanish.” The PC (2001a) observes (at page 397) that, “access pricing is only one factor that shapes the returns to the investments made by access providers”, and later comments (at page 402) that the revenue from interconnection made up for less than two per cent of PSTN revenues in 1999-00.

Although the Productivity Commission maintains that presently the access is not set too low for the purposes of investment, it warns that in the future — i.e. what it describes as the long run — the emergence of downstream market competition will mean that it is less likely that TSLRIC will provide the incumbent with cost recovery. This is evident from its concluding remark (at page 404) that:

...the ACCC might sometimes set access prices that are not sufficient to ensure efficient long run investment in essential telecommunications facilities.

Representatives of Telstra have interpreted the Productivity Commission's findings as being favourable to their claims that the ACCC sets below-cost access prices.<sup>85</sup> However, closer inspection of the statements made by the PC (2001a) outlined above, do not appear to support such inferences. The commentary by the Productivity

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<sup>84</sup> The ACCC (2001) also points to evidence that recent PSTN access undertakings by Telstra were well above charges in other benchmarked countries. However, the Productivity Commission dismisses this evidence and considers (at page 395) that international benchmark data provide “thin evidence” about the appropriate level of the access price.

<sup>85</sup> This claim is made in “Anderson's view lacks appeal”, by Henry Ergas, *Australian Financial Review*, 23 April 2002, and “Off with Their Heads”, by Henry Ergas, *Business Review Weekly*, 15 August 2003.



Commission does not at any stage definitively conclude that access to PSTN services has been under-priced. All conclusions from the report use qualifying language such as “may”, “might” or “is likely”. Finally, the timeframe of the long run, when the PC (2001a) suggests under-pricing problems “may” occur, is never defined and could be many years in the future.

#### 4.6.2.2 *The Investment in the PSTN*

PC (2001a) outlines (at page 399) that, “Telstra has claimed that the access regime reduced its incentives to invest in the PSTN telecommunications network”. In assessing this claim, the Productivity Commission highlights that there has not yet been any evidence of a negative effect upon investment in Telstra’s PSTN services. This is illustrated by a number of separate statements:

...investment in the PSTN has probably not — to date — been adversely affected by regulated access pricing...(at page 399);

...investment has been very substantial in the last few years...(at page 400);

...concern about an imminent crisis in PSTN investment is misplaced. (at page 402); and

Investment has been substantial in recent years. (at page 403)

Evidence that there has not been deterioration in the level of investment in the PSTN network is found from:

- the nominal value of network components having grown by a trend rate of 6.4 per cent per annum from 1994-95 to 1999-00;<sup>86</sup>
- growth in PSTN components comparing favourably with the mobile network;<sup>87</sup> and
- services dependent on Telstra’s network quality — aside from those in rural and remote areas — having “improved over time” and being “high by world standards”.<sup>88</sup>

In making its findings, the Productivity Commission does not however go as far as the ACCC (2001), which claims that investment has not been damaged by access pricing. The Productivity Commission maintains that such conclusions should not be drawn. It

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<sup>86</sup> PC (2001a) at page 400.

<sup>87</sup> *Ibid.*

<sup>88</sup> *Ibid* at page 402.

states (at page 400) that the empirical evidence does not show what would happen to investment if prices were higher, it “only indicates that catastrophic investment effects have been avoided”. While the Productivity Commission later remarks (at page 401) that “investment effects are not likely to be large”, it warns (at page 404) that “uncertainty over regulated prices is likely to be a barrier” to new investments being undertaken.

Although the Productivity Commission does not find there has been a decrease in investment in the PSTN, as was the case for the access price, it makes a qualified conclusion about whether the TSLRIC regime has been harmful for investment.

For the core PSTN, the risk of adverse investment effects from the ACCC’s regulated access prices are not likely to be currently significant, although they may become more pronounced over the medium run as competition further develops in downstream markets.

Recent evidence does indicate that over the past two years there has been a decrease in Telstra’s operating capital expenditure.<sup>89</sup> However, given that there was a strong increase in operating capital expenditure from 1995 to 2000, it appears that these decreases can be explained by factors other than the impact of the access regime.<sup>90</sup>

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<sup>89</sup> Telstra’s 2001-02 Annual Report, available at [http://www.telstra.com.au/investor/docs/company\\_overview.pdf](http://www.telstra.com.au/investor/docs/company_overview.pdf), outlines at page 100 that between 2000-01, operating capital expenditure fell by 12.4 per cent from \$4.73 billion to \$4.14 billion, and from 2001-02 dropped a further 13 per cent to \$3.6 billion.

<sup>90</sup> For example, amongst other things, this decrease in capital expenditure may reflect the stated objective of Telstra to engage in “cost reduction efforts”, and the global and domestic downturn in the telecommunications market.

## 4.7 Conclusion

In both the US and Australia there has been a major upheaval in the telecommunications industry over the last twenty years. Although different market structures have been implemented in undertaking these reforms, regulators in both countries have chosen to adopt the FL cost-based access regime known as TELRIC/TSLRIC, to price access to the network. Designed to approximate the long-run marginal or incremental cost of production and mimic the price arising in a competitive access market, the TELRIC/TSLRIC model has been the subject of much criticism. The FL cost standard chosen by the FCC and ACCC has been considered inappropriate, as it calculates the costs of a hypothetically-efficient network. According to critics this estimate has imposed additional uncertainty upon the access provider, as the prohibitive informational requirements forces regulators to incorporate unrealistic and arbitrary assumptions in its calculations. Ultimately, it has led to claims that TELRIC/TSLRIC systematically under-prices access, and results in undesirable efficiency outcomes for society.

The analysis here suggests that critics have over-stated the adverse impact of the FL cost regulation employed in the US and Australian telecommunications. Claims about the problems associated with hypothetical efficient costs appear to overlook that TELRIC/TSLRIC calculations combine a scorched-node approach, with best-in-use technology. By doing this, regulators limit the amount of arbitrariness and uncertainty associated with the estimation of the FL costs of the network, and in practice estimate something that is closer to the actual efficient FL costs of the network. However, even if there is some uncertainty, certain arguments relating to the price mark-ups to account for this appear to suffer from the same practical flaws as the ECPR, as they can potentially reclassify rents as a cost. Further, arguments about the problems of uncertainty consistently ignore the first-mover advantage experienced by an incumbent, and the offsetting strategic incentive to invest. If the strategic flexibility associated with earlier investment is taken into account in the application of a real options approach, it has been suggested that the access price may even decrease below the TELRIC/TSLRIC-based price.

In the US, the introduction of TELRIC has stimulated an increase in the number of competitors in the local-exchange market, but had little or no impact upon the revenue shares and profitability of incumbent local exchange carriers. The ability of ILECs to

maintain such large market shares may indicate that these firms have managed to retain some market power in the industry. It was suggested that this could be due to barriers to entry arising from scale and scope economies, large sunk costs, or strong customer inertia. The sustained dominance of ILECs appears to provide an alternative explanation for why compared with other deregulated telecommunications markets, there has been less investment observed in US local telecommunication market.

The analysis of the Productivity Commission suggests that presently, claims about the under-pricing or over-pricing of access to the PSTN are difficult to assess in Australia. The problem is that, unlike the access providers in the US local telecommunications market, Telstra is a vertically-integrated access provider that has downstream market power. Therefore, regardless of the level of the access charge, Telstra will still receive a high overall price for its final product. For this reason, although the PC (2001a) maintains investment in the PSTN has been substantial over recent periods, it is not willing to make a judgement about whether access is below cost. Its conclusion on the access price really only goes so far as to warn that if there is eventually downstream market competition in the future, a below-cost access price at that time is likely to have an adverse effect upon investment.

It is probably still too early to draw any strong conclusions about the long-term effects upon innovation and investment. However, the early signs in both the US and Australian telecommunications market suggests that the predictions and forecasts of under-investment and network atrophy resulting from the FL cost-based prices have been exaggerated.

# **CHAPTER 5: BACKWARD-LOOKING AND FORWARD-LOOKING COST REGULATION ON AN EXISTING INVESTMENT**

## **5.1 Introduction**

This Chapter uses a simple model where there is a constant cost-decreasing rate of technological progress in the industry, to examine the impact that the method of asset valuation used by the regulation has on efficiency. It compares the outcomes when backward-looking (BL)/original/historical/embedded and forward-looking (FL)/current/replacement cost regulation are applied to value an existing investment.

### **5.1.1 The Existing Literature on FL Cost Regulation**

As outlined in Chapter 4, the potential for inefficiency under BL cost regulation has been well documented, and recognition of its inadequacies has led many regulatory authorities to recently adopt FL cost regulation. Australian regulators have followed this trend, and FL costs are now used to determine the regulated access price in a number of public utility industries. The ACCC (1997) provides an example of the advantages regulators normally associate with the use of FL costs, when it states (at page 29, footnote 36) that, “forward looking rather than historic costs will result in the more efficient use of, and investment in, infrastructure.”

Despite the purported efficiency gains and the widespread acceptance of FL cost regulation, until recently, there have been few attempts to analyse the regime formally. Further, some of the findings of these papers have not been particularly favourable towards adopting FL cost regulation. Such outcomes are reflected by Laffont and Tirole (2000), who state (at page 148) that the broad regulatory consensus favouring FL costs is “unfortunately supported by little economic argument”; and Guthrie, Small and Wright (2001), (hereafter GSW (2001)), who remark (at page 1) that although “widely regarded as being efficient, this practice [of FL cost regulation] has not been formally analyzed”. A summary of some the recent works formally assessing FL costs is provided here.

Salinger (1998) and Laffont and Tirole (2000) (in Section 4.4, pages 148-61), examine the impact of FL cost regulation. They establish a number of different models to summarise and capture the relevant issues the regulator should consider when adopting FL costs. In particular, they explore how the FL cost-based access price should be adjusted to ensure the firm is adequately compensated for such things as: technological progress, economic stranding, common costs and deregulatory takings.

Hausman (1997, 1999a) and Mandy (2002a, 2002b) use models to critically assess the FL TELRIC/TSLRIC regime employed by the FCC. Both allege that TELRIC underprices access. Hausman claims that the FCC fails to account for the decrease in construction costs due to productivity improvements in the industry, while Mandy illustrates that TELRIC understates costs by comparing the FL cost model with a competitive-equilibrium-pricing rule. Papers using real option theory also reach a similar conclusion about the under-pricing of access, although as outlined in Chapter 4, their results typically suggest that much larger mark-ups are required in the access charge.<sup>1</sup>

GSW (2001) compare investment timing and welfare under BL and FL cost regulation.<sup>2</sup> They establish a model where a regulated monopoly must decide when to undertake an irreversible investment that is subject to stochastic costs following geometric Brownian motion. In their framework, BL cost regulation yields a constant access price, while FL cost regulation yields an uncertain access price that follows the pattern of the stochastic costs over time. The combination of irreversibility and uncertainty leads to real option theory being used to assess the constant BL and uncertain FL cost-based access price. Under both regimes, the regulated monopoly undertakes the investment in the essential infrastructure at a time where it is fully compensated for its expected costs.

From their analysis, GSW find that a higher rate of return is required under FL cost regulation to account for the additional uncertainty associated with the regime. More significantly though, with the aid of numerical simulations, they show that the constant BL cost-based access price, generally induces earlier investment and higher welfare

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<sup>1</sup> Hausman (1997, 1999a) initially illustrates that TELRIC/TSLRIC under-prices access because it does not account for cost-decreasing technological progress. Later in each of these papers, he establishes that it is under-priced because the FCC fails to use real option theory to account for the uncertainty and irreversibility associated with local telecommunication investments.

<sup>2</sup> They also compare BL and FL cost-based access prices with some arbitrarily determined constant access price that is unrelated to costs. It is found that in general some form of cost regulation is desirable for earlier investment and efficiency.

than the uncertain FL cost-based access price. Where there is medium-to-high volatility in cost, the BL rule always dominates the FL rule. When there is low volatility, FL cost regulation may induce earlier investment timing and higher welfare than BL cost regulation. However, this outcome is only possible if the cost of the investment drifts upwards over time. Table 5.1.1 summarises the outcomes of GSW in relation to timing and welfare.

**TABLE 5.1.1 COMPARING BL AND FL COST RULES IN THE GSW (2001) MODEL**

Volatility in Cost	Drift in Cost	Investment Timing	Welfare
High	Upward	BL earlier	BL higher
	Downward	BL earlier	BL higher
Medium	Upward	BL earlier	BL higher
	Downward	BL earlier	BL higher
Low	Upward	Stronger drift ⇒ FL earlier Weaker drift ⇒ BL/FL	Stronger drift ⇒ FL higher Weaker drift ⇒ BL/FL
	Downward	BL earlier	BL higher

The outcome achieved by GSW has significant policy implications as it suggests that FL cost regulation should only be applied in the unusual circumstances where costs in the regulated industry are increasing over time. This leads GSW to conclude (at page 20) that, “except in the special situation...backward looking rules should be adopted.” Their result may obviously be of particular relevance to the telecommunications industry, which uses FL cost regulation, yet experiences a rapid rate of cost-decreasing technological progress.

Evans and Guthrie (2002) also compare investment timing and welfare under BL and FL cost regulation in a model of uncertain costs, where there are no incentives to cost-pad. Similar to GSW, they conclude that BL cost regulation is preferable in industries where there are higher levels of cost-decreasing technological progress. In particular, Evans and Guthrie conjecture (at page 5) that because of its rapid cost-decreasing technological progress and future cost uncertainty, the telecommunications industry “is more a candidate for historical-cost regulation than are more technologically stable industries such as gas and electricity transmission”.

### 5.1.2 The BL and FL Cost Regulation Debate

The debate over whether the regulator should value the capital assets of the firm using the higher original/historical/embedded/backward-looking costs, or the lower replacement/current/forward-looking costs, has been around for a number of decades. For example, Bonbright (1961) reviewed the merits of using BL and FL costs in designing public utility rates,<sup>3</sup> while Westfield (1965) examined the impact BL and FL costs had on the incentives for a ROR-regulated firm to engage in a price conspiracy with the input seller. Temin (1997) notes that in regulatory proceedings, AT&T argued for the use of FL costs to justify lower rates in the 1960s, yet advocated the use of BL costs to justify higher rates in the late 1970s.<sup>4</sup>

In terms of public policy, the analysis in Chapter 4 suggests that while there has been some ambiguity over the nature of the cost debate in Australian utility industries, in US local telecommunications, the BL versus FL cost debate is no longer a major consideration. The problems associated with traditional BL costs has led to the strongest critics of the FL TELRIC regime, such as Kahn et al. (1999), to state (at page 324) that there is “widespread agreement” amongst economists that BL cost regulation should not be used. Kahn et al., Weisman (2000) and Noam (2002) outline that in US local telecommunications, the cost debate has instead been over the type of FL cost regulation the regulator should employ as the basis for pricing. Kahn et al. and Weisman claim that presently the regulator uses the FL costs of a hypothetical efficient entrant, when it should instead use the actual FL costs of the network of the incumbent.

The recent theoretical work by GSW and Evans and Guthrie not only outlines the adjustment that needs to be made to the fair rate to account for the use of FL costs under uncertainty, they also suggest that the BL versus FL cost debate may need to be reconsidered by regulators. Both papers highlight that if the typical incentive problems associated with the use of actual cost regulation are ignored, there will be instances where the adoption of BL costs leads to a higher level of welfare than the use of FL cost regulation.

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<sup>3</sup> See Bonbright (1961) Chapters XI-XIV.

<sup>4</sup> AT&T used these contrasting arguments strategically, in an attempt to prevent entry to the industry. This is reflected by Temin’s comment (at page 16) that, “AT&T acted consistently in seeking to limit entry, but inconsistently in terms of pricing rules”.



### 5.1.3 The Results and Contributions of this Chapter

This Chapter examines the impact BL and FL cost regulation has on an existing investment, by establishing a model where there is a constant exogenous rate of cost-decreasing technological progress, no uncertainty, and no incentive to cost-pad. The basic framework is similar to that used by Hausman (1997, 1999a) and Laffont and Tirole (2000) in Section 4.4.1.3. Further, as it is assumed there is no cost padding, only one type of technology is used in the industry, and the rate of technological progress on this asset is known, there is no need to distinguish between actual and hypothetical efficient FL cost regulation in the work done here.

The analysis illustrates that where there are decreasing costs over time and no uncertainty, in order to achieve cost recovery on an existing investment under FL cost regulation, the firm must be allowed to earn a higher depreciation rate than under BL cost regulation. The appropriate increase in the depreciation rate ensures that the firm is indifferent between the constant net cash flow and price schedule under BL cost regulation, and the decreasing net cash flow and price schedule that arises over time under FL cost regulation. The required adjustment in the depreciation rate is shown to be a specific application of the “Invariance Proposition” of Schmalensee (1989).

While the different depreciated schedules are irrelevant for the firm, there will be some impact upon society. It is illustrated that there is a greater benefit to society from having a constant BL cost-based price charged over time, rather than a FL cost-based price that decreases over time. As the basic assumptions used here are similar to those of GSW (2001), it suggests that their findings in favour of a BL cost-based price, can be achieved even when abstracting from the issues of uncertainty or investment timing. It is however shown that FL cost regulation may be preferable to a BL cost rule in a deregulated market.

The structure of the Chapter is as follows. Section 5.2 establishes the model, and derives the fair rate of return required on the existing investment in order to achieve cost recovery under both BL and FL cost regulation. The following Section examines the different net cash flow and price schedules generated under the different depreciations rates allowed under BL and FL cost regulation. These outcomes are then used to capture some criticisms of the FL TELRIC/TSLRIC regulation outlined in Chapter 4. Section 5.4 explores welfare under BL and FL cost regulation, while Section 5.5 details that the appropriately adjusted fair rate under FL cost regulation, may be beneficial for a firm that is subject to deregulation. Section 5.6 concludes the analysis.

## 5.2 The Fair Rate for Cost Recovery under BL and FL Cost Regulation

This Section establishes the model used to compare BL and FL cost regulation of an existing investment. Assuming there is an existing essential infrastructure, no uncertainty, no competition to provide access, and a constant rate of cost-decreasing technological progress; the fair rates of return required to achieve cost recovery under BL and FL cost regulation are found. The basic framework adopted here is similar to that used by Hausman (1997, 1999a) and Laffont and Tirole (2000).<sup>5</sup>

### 5.2.1 Assumptions of the Model

For simplicity, the model here assumes that:

- there is continuous time  $t$ ;
- the firm makes the investment in the infinitely-lived essential infrastructure during the initial time period  $t = 0$ ,<sup>6</sup> at a cost to the firm and society of  $C_0$ ;<sup>7</sup>
- once the investment is undertaken, a fixed amount of the infrastructure is provided instantaneously. The facility has the capacity to supply any level of access that is demanded without the need for additional investment;<sup>8</sup>
- no other firms supply the essential infrastructure, and the access provider does not compete in any related downstream market;
- at each instance, the firm faces a constant operating cost in each period of  $O$ ;
- the industry is subject to some known constant rate of technological progress  $\theta > 0$ .<sup>9</sup>

The efficient FL cost of a hypothetical entrant replacing the infrastructure at any future instant in time  $t$  is then  $C_t$ , where  $C_t = C_0 e^{-\theta t}$ ,  $\forall t$ ;

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<sup>5</sup> See Section 4.4.1.3 of Laffont and Tirole (2000) at pages 151-4. Neither Laffont and Tirole or Hausman however, use the model to undertake the type of comparisons between BL and FL cost regulation that are made in this Chapter.

<sup>6</sup> The investment timing is exogenously given in this model. A model where investment timing is endogenously determined is established in the analysis done in Chapters 6 and 7.

<sup>7</sup> The assumption of an infinitely-lived investment is used by Gans and Williams (1999a), Gans (2001) and GSW (2001). It also seems reasonable in light of the fact that many capital assets of public utilities are generally long-lived.

<sup>8</sup> This is a “super” natural monopoly assumption, as it implies that the access provider can service whatever level of demand arises in the industry, and that no additional investments in capacity are required. The assumption here of a natural monopoly with infinite capacity is consistent with that adopted by Gans and Williams (1999a) and Gans (2001).

- the normal market rate of return is  $r > 0$ . As there is no uncertainty associated with the net cash flows derived by the firm under either BL or FL costs, the appropriate choice for  $r$  is the risk-free rate of return;
- there is no physical deterioration of the asset,<sup>10</sup> nor any inflation in the industry;
- the demand curve for access is fixed over time, and the demand for access is own-price inelastic;<sup>11</sup>
- either BL or FL cost regulation are applied to the asset at time 0;
- regardless of whether the regulator values the capital assets using BL or FL costs, the fair rate  $f$  is set to ensure that the net present value derived by the firm from the investment is always zero (i.e.  $NPV_f = 0$ );
- under both BL and FL cost regulation, the firm is only allowed to charge a linear price for access  $p$ . No multi-part tariffs are used;<sup>12</sup> and
- from charging the access price  $p$  and supplying  $q$  units of access, the infrastructure provider earns revenue in each period of  $R$ . The net cash flow or operating profit that is derived by the firm in each period  $\pi$ , is equal to total revenue  $R$  minus the operating costs of the firm  $O$  (i.e.  $\pi = R - O$ ).

### 5.2.2 The Fair Rate of Return with BL Cost Regulation

The subscript  $B$  is used to denote outcomes under BL cost regulation. Subsequently, when the firm is allowed to earn a regulated rate of return on the historical cost  $C_0$ , the access provider will receive a constant net cash flow in each period of  $\pi_B$ , from charging the constant access price  $p_B$  on each of the  $q_B$  units of access it supplies. To derive the

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<sup>9</sup> Laffont and Tirole (2000) note (at page 153) that although the assumption of an exogenous rate of technological progress limits the scope of the model, it may be acceptable in certain circumstances. They provide the example of the technological progress on the microprocessors used in switches, which have largely been driven by factors outside the telecommunications industry.

<sup>10</sup> This assumption is made to avoid the complication associated with having to constantly replace the deteriorating portions of the asset with new capital that has a lower cost. Such a process would lead to the initial value of the investment increasing and create the scope for capital gains. The assumption of no physical deterioration is consistent with the analysis done by Gans and Williams (1999a) and Gans (2001).

<sup>11</sup> The assumption of demand being own price inelastic ensures that, the net cash flow of the firm decreases when there is a fall in the linear access price charged. This is not only consistent with the analysis of GSW (2001), but also the arguments raised in practice by regulated firms, which often automatically associate a decrease in the regulated price with a fall in allowed earnings.

<sup>12</sup> While two-part access tariffs are common in rail track and natural gas transportation, they do not appear to be used for pricing interconnection to telecommunications networks. For a discussion of this see Biggar (2001) and Chapter 6, Section 6.6.

allowed fair rate of return under BL cost regulation, the discounted net present value earned by the access provider is set equal to zero (i.e.  $NPV_{f_B} = 0$ ).

$$NPV_{f_B} = \int_0^{\infty} \pi_B e^{-rt} dt - C_0 = 0 \quad (5.2.1)$$

Solving this, the period-to-period allowed net cash flow or operating profit under BL costs will be,

$$\pi_B = rC_0 \quad (5.2.2)$$

and the allowed fair rate of return on capital under BL cost regulation  $f_B$  is,

$$f_B = r \quad (5.2.3)$$

In equation (5.2.3)  $r$  represents the opportunity cost of capital associated with not investing in a similar risk-free asset. As there is no physical deterioration or capital gain on the asset, the allowed rate of economic depreciation, or allowed the rate of return “of” the asset under BL cost regulation  $d_B$ , is set equal to zero (i.e.  $d_B = 0$ ).

From equation (5.2.2), the regulated BL cost-based linear access price  $p_B$  can be derived. As by assumption, the net cash flow is equal to  $\pi_B = R_B - O$ , where  $R_B = p_B q_B$ , the expression for the access price will be,

$$p_B = \frac{rC_0 + O}{q_B} \quad (5.2.4)$$

Having a constant BL cost-based net cash flow and access price is consistent with the analysis of GSW (2001).

### 5.2.3 The Fair Rate of Return with FL Cost Regulation

If the regulator uses FL costs in this framework, then at any time  $t$ , the net cash flow the firm is allowed to earn will be directly related to the hypothetical efficient cost of replacing the asset at that instant. Subsequently, with decreasing costs over time, the allowed net cash flow at each instant under FL cost regulation will also be decreasing. Using subscript  $t$  to denote some arbitrary point in time and subscript  $F$  to denote the outcomes under FL cost regulation, with an allowed fair rate of return under FL costs of  $f_F$ , the allowed net cash flow over time follows the pattern:

$$\pi_{Ft} = f_F C_t = f_F C_0 e^{-\theta t}, \forall t \geq 0 \quad (5.2.5)$$

Therefore, where  $\pi_{F0}$  is the allowed net cash flow under FL cost regulation during the initial time period, it follows that the net cash at any time  $t$  will be

$$\pi_{Ft} = \pi_{F0} e^{-\theta t}, \forall t \geq 0 \quad (5.2.6)$$

To find the expression for the net cash flow at any time  $t$  and the fair rate of return  $f_F$ , the net present value derived by the firm subject to FL costs, is set equal to zero (i.e.  $NPV_{fF} = 0$ ).

$$NPV_{fF} = \int_0^{\infty} \pi_{Ft} e^{-rt} dt - C_0 = 0 \quad (5.2.7)$$

Substituting equation (5.2.6) into (5.2.7) yields,

$$NPV_{fF} = \int_0^{\infty} \pi_{F0} e^{-(\theta+r)t} dt - C_0 = 0 \quad (5.2.8)$$

This can be solved for an allowed net cash flow at time 0 of,

$$\pi_{F0} = (\theta + r) C_0 \quad (5.2.9)$$

or alternatively, an allowed net cash flow at any time  $t$  of,

$$\pi_{Ft} = (\theta + r) C_0 e^{-\theta t}, t \geq 0 \quad (5.2.10)$$

This implies that, in order to adequately compensate the firm under a FL cost regime, the regulator must provide the investor with the regulated fair rate,

$$f_F = (\theta + r) \quad (5.2.11)$$

From equation (5.2.10), at any given time  $t$ , the regulated linear access price from FL cost regulation is,

$$p_{Ft} = \frac{(\theta + r) C_0 e^{-\theta t} + O}{q_{Ft}}, t \geq 0 \quad (5.2.12)$$

As the demand for access is assumed to be own-price inelastic, this FL cost-based access price will decrease over time in a similar manner to the net cash flows or operating profit. This is similar to the outcome in GSW (2001) when there is a downward drift in cost.

As in this framework the constant positive operating costs merely have an additive effect on the level of the price and net cash flow, it makes no difference to the overall outcome. Consequently, throughout the remainder of this Chapter the operating costs

are set equal to zero (i.e.  $O = 0$ ), and the terms revenue, net cash flow or operating profit are used interchangeably.

A comparison of the fair rates under BL and FL cost regulation, and the resulting net cash flow and price schedules is done in the following Section.

### 5.3 Comparing BL and FL Cost Regulation

This Section uses the model from Section 5.2 to compare the outcomes under BL and FL cost regulation. To ensure the firm recovers the cost of the investment, the fair rate under FL cost regulation must be set higher than the fair rate allowed under BL cost regulation. As there is no uncertainty and the regulator imposes a capital loss on the firm by valuing the asset at the FL cost that is decreasing over time, the most appropriate way to increase the fair rate is through an increase in the allowed regulatory depreciation rate. This leads to the simple principle that, to achieve cost recovery with a constant cost-decreasing rate of technological progress and FL cost regulation, the rate of decrease in the asset value by the regulator must be met by a corresponding increase in the allowed depreciation rate. It is outlined that the required adjustment to the depreciation rate to account for FL costs, is just a specific application of the “Invariance Proposition” highlighted by Schmalensee (1989).

The framework from Section 5.2 is also used to illustrate the differing net cash flow and price schedules under BL and FL cost regulation, and to assess the contrasting criticisms outlined in Chapter 4, that FL TELRIC/TSLRIC regulation can under- or over-compensate the firm. The analysis here highlights that the opposing claims appear to identify the same problem. The regulator uses FL costs, yet only allows the firm to earn a depreciation rate based on the BL cost of the asset. The difference in the analysis of Holm (2000), who argues that FL cost-based access prices can over-compensate the firm, is that in his example the cost of the asset is actually increasing over time.

#### 5.3.1 The Allowed Fair Rate under BL and FL Cost Regulation

From equations (5.2.3) and (5.2.11), it is apparent that in order for the access provider to recover the cost of investment, the allowed fair rate under FL cost regulation must exceed the allowed fair rate under BL cost regulation by the amount  $\theta$  (i.e.  $f_F > f_B$  or  $f_F = f_B + \theta$ ). This outcome arises because the regulator must compensate the firm for the capital loss it imposes when it values the existing assets using FL costs that are decreasing over time by the known rate of technological progress  $\theta$ . As there is no uncertainty associated with the net cash flows earned under FL cost regulation here, there is no adjustment made to the market rate of return on the asset, and it remains at the risk-free rate  $r$ . To account for FL costs, the regulator should instead adjust the fair

rate of return, by allowing the firm a higher depreciation rate on the asset.<sup>13</sup> That is, the regulator sets the allowed rate of depreciation at  $d_F$ , where,

$$d_F = \theta > d_B = 0 \quad (5.3.1)$$

The allowed fair rate of return under FL cost regulation in equation (5.2.11), can then be alternatively expressed as the sum of the allowed return on the asset  $r$ , and the allowed return of the asset  $d_F$ .

$$f_F = (r + d_F), \text{ where } d_F = \theta \quad (5.3.2)$$

The adjustment to the fair rate under FL costs illustrates that the methodology used by the regulator to value the asset, must be directly reflected in the fair rate of return that the firm is allowed to earn. This leads to the simple principle being established that in order to achieve cost recovery, the rate of decrease in the asset value by the regulator in each period must be met by an identical increase in the allowed depreciation rate. Provided this occurs, the difference between the depreciation schedules under BL and FL cost regulation will be irrelevant to the regulated investor. It turns out this simple principle, and the subsequent irrelevance of the depreciation schedules, is a specific application of the “Invariance Proposition” highlighted by Schmalensee (1989).

### 5.3.2 The Invariance Proposition

The economic value of an asset at any instant is equal to the present value of the future cash flows it generates. Hotelling (1925) was the first to propose a concept of depreciation that was based on the change in the economic value of the asset during each period. Referred to now as economic or Hotelling depreciation, it only corresponds to the standard accounting concepts of depreciation under very special circumstances. Schmalensee (1989) however illustrates that for a ROR-regulated firm, it is possible that any accounting depreciation schedule will be an economic schedule.

The framework used by Schmalensee assumes there is discrete time  $t$ , no competition or taxes, and that the actual earnings of the ROR-regulated firm are equal to the allowed earnings. He then shows that the regulated firm will be fully compensated for

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<sup>13</sup> GSW (2001) also outlines (at page 20) that there should be an increase in the allowed fair rate to account for the use of FL costs. However, in contrast to the analysis here, in their framework the regulator must set a higher fair rate of return, to compensate the incumbent for the increased risk associated that is associated with having uncertain FL costs.



undertaking the investment if the cash flow is adjusted with depreciation at the end of each period  $t$ , so that it is equal to,

$$rC_{t-1} + (C_{t-1} - C_t) \quad (5.3.3)$$

where:  $r$ , is the rate of return the regulator allows on the asset;

$C_{t-1}$ , is the value of the asset in the previous year and is sometimes referred to as the “ratebase”; and

$(C_{t-1} - C_t)$ , is the amount of depreciation that the regulator allows the investor to claim on the asset.

The accounting depreciation schedule chosen by the regulator is now irrelevant. Every accounting depreciation schedule is now also an economic depreciation schedule, and the accounting rate of return will be equal to the economic rate of return earned on the asset. Schmalensee refers to this outcome as the “Invariance Proposition”.<sup>14</sup> To highlight the intuitive properties of the Invariance Proposition, the following bank account analogy is used.<sup>15</sup>

#### 5.3.2.1 The Bank Account Analogy

Suppose that a deposit of 100 dollars is placed in a bank account at time 0 (i.e.  $B_0 = \$100$ ) and the bank pays an interest rate of 10 per cent (i.e.  $r = 0.1$ ). The depositor will then be fully compensated if the bank pays either:

- a cash flow of \$10 at the end of each future year; or
- \$110 at the end of year one, and nothing in any future year; or
- \$60 at the end of year one, \$55 at the end of year two, and nothing in future years; or
- \$50 at the end of year one, \$66 at the end of year two, and nothing in future years; or
- \$70 at the end of year one, \$44 at the end of year two, and nothing in future years.

More generally it can be stated that the depositor will be fully compensated by the bank, if at the end of each time  $t$ , it is paid a stream of cash flows satisfying the expression,

<sup>14</sup> Although Schmalensee was the first to refer to the irrelevance of the accounting depreciation schedule for the regulated firm as an Invariance Proposition, Awerbuch (1992) points out that he was not the first to identify the result. Awerbuch outlines (in footnote 1 at page 68) that, this Proposition was also shown by Kay (1976), Fisher and McGowan (1983), and Edwards, Kay, and Mayer (1987). Boadway and Bruce (1984) derive a similar result in the public economics literature on taxation.

<sup>15</sup> Awerbuch (1992) uses a similar analogy (at page 63) involving a bank loan.

$$rB_{t-1} + (B_{t-1} - B_t) \quad (5.3.4)$$

where:  $rB_{t-1}$ , is the interest payment on the balance in the previous year; and

$(B_{t-1} - B_t)$ , is the level of the withdrawal required from the account in order to compensate the depositor for the decline in the bank balance.

This outcome corresponds to equation (5.3.3) for the ROR-regulated firm, and to highlight that the depositor is fully compensated, the present value of bank payments following equation (5.3.4) is calculated for a deposit held over  $T + 1$  periods.

$$\begin{aligned} PV &= \frac{rB_0 + B_0 - B_1}{1+r} + \frac{rB_1 + B_1 - B_2}{(1+r)^2} + \dots + \frac{rB_{T-1} + B_{T-1}}{(1+r)^T} \\ &= B_0 - \underbrace{\frac{B_1}{1+r} + \frac{B_1}{1+r}}_{=0} - \underbrace{\frac{B_2}{(1+r)^2} + \frac{B_2}{(1+r)^2}}_{=0} - \dots = B_0 \end{aligned}$$

### 5.3.2.2 BL and FL Cost Regulation — An Application of the Invariance Proposition

The allowed fair rates under BL and FL cost regulation both generate cash flows that satisfy the outcome described in equation (5.3.3).<sup>16</sup> For example, under BL costs, as there is no depreciation of the asset, it follows from equation (5.3.3) that to fully compensate the investor, the allowed cash flow at each instant must yield the rate of return  $r$ . In contrast, under FL costs, as the value of the asset depreciates by the constant rate of technological progress  $\theta$ , it follows from equation (5.3.3) that the allowed cash flow at each instant must be adjusted with depreciation, and yield the rate of return  $\theta + r$ . This demonstrates that the allowed fair rate under BL costs, and the principle for adjusting the fair rate to take into account FL costs and ensure the different cash flow schedules under two schemes are irrelevant; both just represent a specific application of the Invariance Proposition outlined by Schmalensee.<sup>17</sup> Consequently, the different depreciation schedules will both be economic schedules, and the fair rate the regulator allows on the asset will be equal to the economic rate of return that is earned by the investor.

<sup>16</sup> The only difference is that continuous time was used in Section 5.2.

<sup>17</sup> Awerbuch (1992) queries how useful the Invariance Proposition is in practice. By using a simple numerical example, he shows that under more realistic circumstances — where the economic and accounting life of the asset differ and there are inter-period tax allocations or a regulatory lag — the Invariance Proposition does not hold.

### 5.3.3 The Dynamics of Net Cash Flow and Price under BL and FL Cost Regulation

The higher fair rate required under FL cost regulation implies that during the earlier time periods, the allowed net cash flow under FL costs exceeds the allowed net cash flow under BL costs. For example, at time 0 the net cash flow under FL cost regulation will be,

$$\pi_{F0} = (\theta + r)C_0 > \pi_B = rC_0 \quad (5.3.5)$$

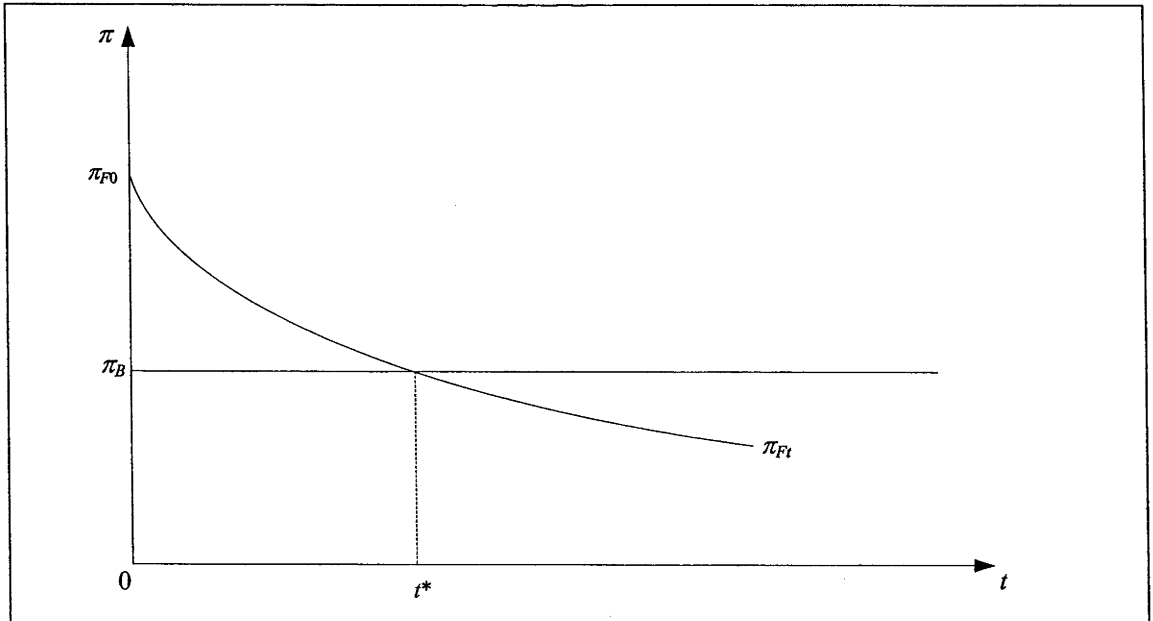
This is done to make up for the allowed net cash flow decreasing over time at the same rate as the hypothetical efficient cost of replacing the asset

The net cash flows under FL cost regulation will exceed the net cash flows allowed under BL cost regulation until some time  $t^*$  is reached, where the net cash flows are equal. Beyond the time  $t^*$ , the net cash flow allowed under BL cost regulation will be higher. To derive an expression for  $t^*$ , equation (5.2.2) is equated with equation (5.2.10), and solved to give

$$t^* = \frac{1}{\theta} \log \left( \frac{\theta + r}{r} \right) \quad (5.3.6)$$

The outcome described here is illustrated in Figure 5.3.1.

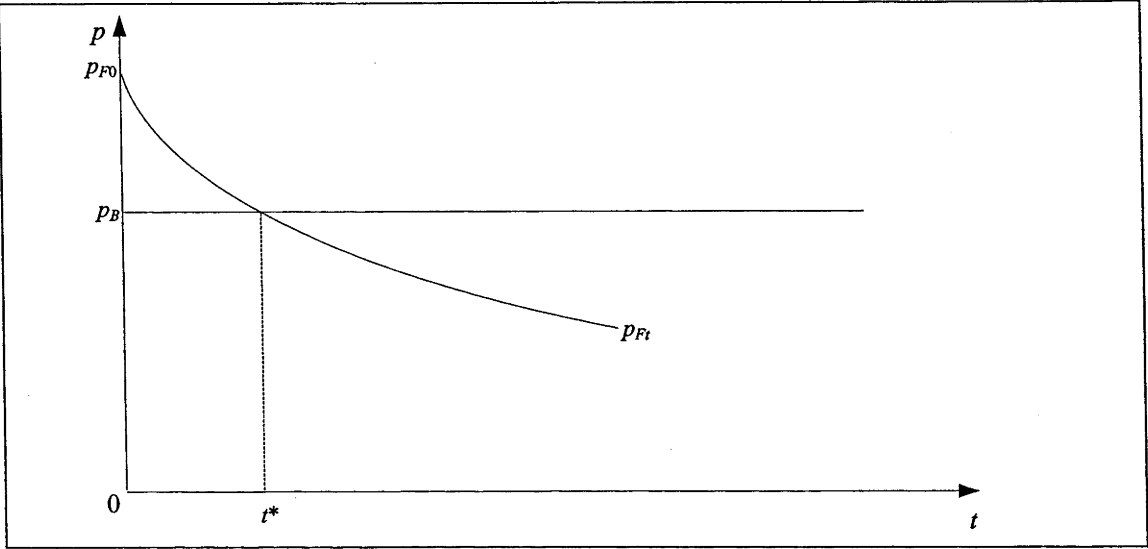
**FIGURE 5.3.1 COMPARING BL AND FL REVENUE FLOWS**



As the demand for access is own-price inelastic, the FL access price follows a similar trajectory over time to the revenue path. This implies  $p_{Ft}$  exceeds the constant BL

access price  $p_B$  until time  $t^*$ , after which time  $p_{Fi}$  is below  $p_B$ . The difference between the linear BL and FL cost-based access price is illustrated in Figure 5.3.2.

**FIGURE 5.3.2 THE BL AND FL COST-BASED ACCESS PRICE**



### 5.3.4 Assessing Contrasting Criticisms of TELRIC/TSLRIC

#### 5.3.4.1 Under-Compensation under TELRIC/TSLRIC

A common theme of many criticisms of FL TELRIC/TSLRIC regulation is that it fails to fully compensate the infrastructure provider for cost of its investment. As outlined in Chapter 4, amongst other things, Hausman (1997, 1999a) claims that under-pricing occurs because the FCC ignores the impact of cost-decreasing technological progress; while Kahn et al. (1999) argue that TELRIC models under-price access by employing traditionally determined regulatory rates of depreciation.

In terms of the model established in Section 5.2, the claims made by Hausman and Kahn et al., amount to the FCC TELRIC models using FL costs to value the asset (i.e.  $C_t$ ), yet only allowing a depreciation rate based on the BL cost of the asset (i.e.  $d_B = 0$ ). That is, the FCC ignores the constant rate of technological progress in the industry  $\theta$ , and sets the fair rate so that,

$$f_{FCC} = r \tag{5.3.7}$$

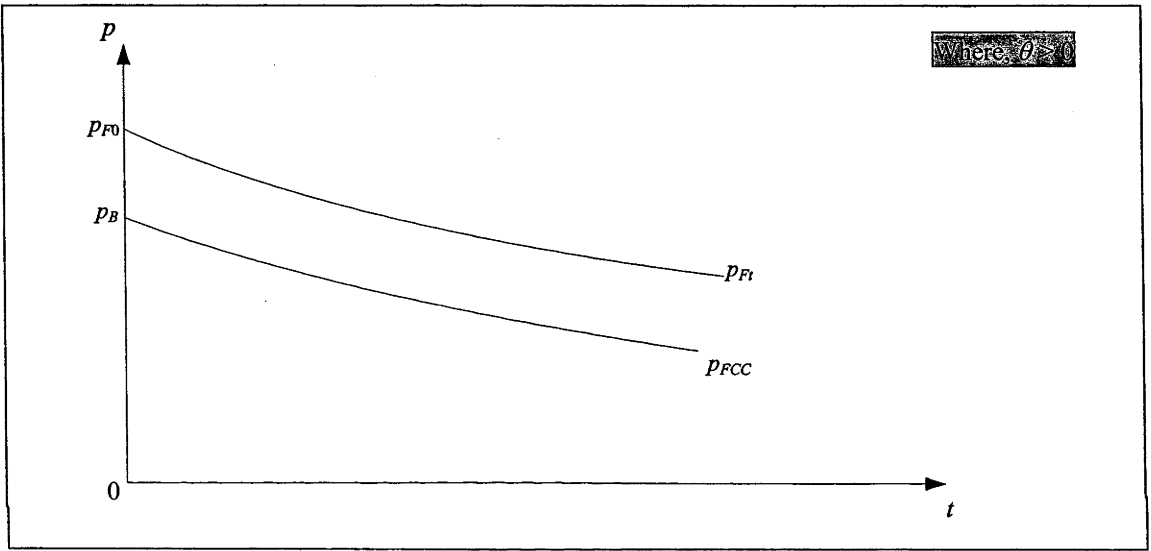
Therefore, the regulator subjects the efficient access provider to a capital loss that it is not compensated for.

As it is assumed for simplicity that there are no operating costs, when the regulator sets the fair rate  $f_{FCC}$ , it follows that the allowed FL cost-based linear access price will be,

$$p_{FCC} = \frac{rC_0 e^{-\theta t}}{q_t}, \forall t \geq 0 \quad (5.3.8)$$

As there is cost-decreasing technological progress (i.e.  $\theta > 0$ ), the regulated price Hausman and Kahn et al. claim that the FCC sets,  $p_{FCC}$ , decreases over time. By comparing the outcome in equation (5.3.8), with the outcome in equation (5.2.12) when  $O = 0$ , it is clear that the access charge  $p_{FCC}$  will be less than the linear price that is required to recover the cost of the investment  $p_{Fl}$ . Figure 5.3.3 illustrates this outcome.

**FIGURE 5.3.3 THE CRITIQUE OF TELRIC/TSLRIC IN THE SIMPLE MODEL**



Further, the failure to recover costs is also apparent from the negative net present value that is now derived from the investment.

$$NPV_{fFCC} = \int_{t=0}^{\infty} (f_{FCC} C_t) e^{-(r-\gamma)t} dt - C_0 = \left( \frac{r}{\theta + r} - 1 \right) C_0 < 0 \quad (5.3.9)$$

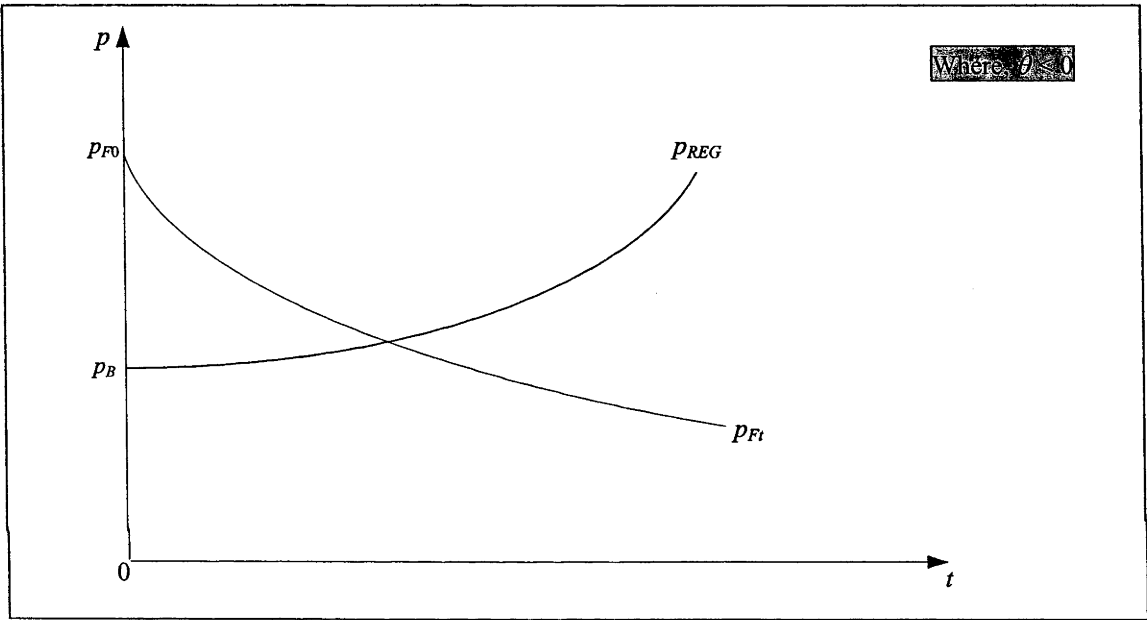
If the claims of Hausman and Kahn et al. are correct, then the pricing regime used by the FCC would constitute an example of a regulatory taking.

#### 5.3.4.2 Over-Compensation under TELRIC/TSLRIC

Holm (2000) expresses reservations about the use of a FL cost-based access price. However, unlike Hausman and Kahn, he suggests FL costs can potentially lead to the regulated firm being over-compensated. For evidence, Holm points to cost estimates provided by OVUM (1998), which established that although the FL cost of the core network had decreased, the local access network had become more costly to build.

At first glance, the critique of the FL cost-based access price by Holm appears very different to that of Kahn et al. and Hausman. However, using the framework from Section 5.2, it is possible to show that he appears to identify a similar problem with FL cost regulation. That is, the regulator applies FL cost regulation to value the asset (i.e.  $C_t$ ), yet only allows a depreciation rate based on the BL cost of the asset (i.e.  $d_B$ ). The implicit difference in the analysis of Holm is that in order to reflect the increased cost of investing in the future, the term  $\theta$  must now be assumed to be less than zero (i.e.  $\theta < 0$ ).

**FIGURE 5.3.4 FL COST-BASED ACCESS PRICES LEADING TO HIGHER PRICES**



Subsequently, the expressions in equation (5.3.7), (5.3.8) and (5.3.9), can also be used to capture the outcome described by Holm. As Figure 5.3.4 shows, when  $\theta < 0$ , the regulated linear access price  $p_{REG}$  will now increase over time, and the expression for the net present value in equation (5.3.9) will be greater than zero. The positive net present value demonstrates that the regulated firm derives economic profit or rents from the investment. This arises because the regulator provides the firm with the benefit of a capital gain that is not accounted for — i.e. taken away — through any adjustment in the allowed depreciation rate. The outcome illustrates that if economies of scale and scope cause increasing costs over time, it is possible for traditionally-determined regulatory rates of depreciation to actually over-compensate the FL cost-regulated firm.

## 5.4 Comparing Welfare under BL and FL Cost Regulation

GSW (2001) found that with stochastic costs that drift downward over time, a constant BL cost-based price induces earlier investment timing and greater benefit to society, than an uncertain FL cost-based price that is decreasing over time. They attribute this outcome to the greater uncertainty associated with FL cost regulation, and conclude that in most realistic cases, BL cost regulation should be adopted by the regulator. This Section employs basic assumptions similar to those used by GSW to show that even without considering the issues of uncertainty or investment timing, a constant BL cost-based price will be better for society than a FL cost-based price that is decreasing over time. The result suggests that it is not necessary to appeal to uncertainty to argue that BL costs are preferable to FL costs.

The impact of BL and FL regulation on society is compared using a model similar to that outlined in Section 5.2. The main difference here is that it is assumed there is discrete time and that the investment lives for a finite time period. From this, it is established that for an existing asset subject to decreasing costs over time and no uncertainty, a constant BL cost-based access price is better for society than a FL cost-based access price that also recovers the cost of the investment. This demonstrates FL rules achieve worse outcomes for society even when the standard concerns outlined in Chapter 4 are ignored. That is, FL cost regulation:

- fails to allow full cost recovery on the investment;
- creates additional uncertainty; and
- delays future investment in new technology.

It is shown here that the welfare dominance of a constant BL cost-based access price over time will arise if there is a demand curve for access that meets standard regularity conditions. Although GSW do not make any explicit assumptions about the demand for access, their assumptions are consistent with having such a well-behaved demand curve.

### 5.4.1 Assumptions of The Model

To compare welfare under BL and FL cost regulation of an existing investment, when there is technological progress in the industry, it is assumed for simplicity here that:

- there is discrete time  $t$ ;

- the investment in essential infrastructure occurs at time  $t = 0$  at a cost to the firm and society of  $C_0$ . The asset is immediately subject to cost-based regulation;
- only one firm supplies the essential infrastructure, and the essential infrastructure supplier cannot enter the downstream retail market;
- the essential infrastructure has sufficient capacity to serve any level of demand for access that arises in the industry;
- the industry is subject to a constant rate of cost-decreasing technological progress  $\theta$ . Subsequently, the FL cost — i.e. the costs faced by a hypothetical entrant to the industry at any time  $t$  — is,  $C_t = C_0(1 - \theta)^t$ ,  $0 < \theta < 1$ ;
- there is no inflation, no physical depreciation of the infrastructure, and originally no discount rate or opportunity cost of funds (i.e.  $r = 0$ );
- the investor supplies access to a single firm at time  $t = 1$ , and the essential facility continues to operate for  $T$  periods, i.e.  $t = 1, 2 \dots T$ ;
- the access seeker uses access as an input to provide a final product to a single customer in a downstream retail market;
- the inverse demand curve for access  $p(q)$  is downward sloping i.e.,  $p'(q) < 0$  and does not shift over time. The meaning of “demand for access” where there is both a retailer and downstream customer, is explored in greater detail in Section 5.4.2.1;<sup>18</sup>
- there is no ongoing expense associated with providing access to the essential facility in each time period  $t = 1, 2 \dots T$ . Hence, the short-run marginal cost of production is zero (i.e.  $SRMC = 0$ );
- the firm charges a linear access price  $p$ , and use of the infrastructure generates revenue or net cash flow during each time period of  $\pi(p(q))$ ;
- where  $q_{\max}$  and  $q_m$  are the levels of usage of the facility in each period at a zero and an unregulated monopoly price, the revenue or net cash flow function  $\pi(q)$ , has the properties:
  - $\pi(0) = 0$ ,  $\pi(q_{\max}) = 0$ ;
  - $\pi'(q) = MR(q) = p'(q).q + p(q)$ ;

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<sup>18</sup> Although GSW (2001) do not specify an underlying demand curve for access, the assumption of some fixed yet downward-sloping demand for access is consistent with the assumptions in their analysis.



- $\pi(q_m) = \pi_{\max}$ , as at  $q_m$  the marginal revenue of production is equal to the zero short-run marginal cost of production (i.e.  $\pi'(q_m) = SRMC = 0$ );
  - $\pi'(q) > 0$ , if  $0 < q < q_m$ ;
  - $\pi'(q) < 0$ , if  $q_m < q < q_{\max}$ ; and
  - $\pi''(q) = p''(q).q + 2p'(q)$ .
- from accessing the essential infrastructure, the “consumer” derives a level of surplus in each period of  $CS(q)$ . The meaning of the term “consumer”, where there is a retailer and a customer in the downstream market is examined in greater detail in Section 5.4.2.1. Consumer surplus derived in each period has the properties:
- $CS(q) = V(q) - p(q).q$ , where  $V(q) = \int_0^q p(q) dq$ ;
  - $CS(0) = 0$ ,  $CS(q_{\max}) = CS_{\max} > \pi_{\max}$ , where  $CS_{\max}$  denotes the maximum consumer surplus derived from having access to the facility;
  - $CS'(q) = -p'(q).q < 0$ ; and
  - $CS''(q) = -(p''(q).q + p'(q))$ .
- the measure of welfare to society, or the total surplus derived from using the infrastructure during each period is  $S(q)$ .  $S(q)$  is the sum of the consumer surplus and the revenue to the access provider (i.e.,  $S(q) = CS(q) + \pi(q)$ );
- $S(q)$  has the properties:
- $S(0) = 0$ ,  $S(q_{\max}) = CS(q_{\max}) = S_{\max} > \pi_{\max}$ ; and
  - $S'(q) = p(q) > 0$  and  $S''(q) = p'(q) < 0$ .
- under BL and FL cost regulation, the regulator allows the firm to generate a net cash flow in each period that recovers all costs associated with the investment. Adopting the same subscripts used in Section 5.2 for BL and FL cost regulation, implies that:
- $\sum_{t=1}^T \pi_{Ft} = T.\pi_B = C_0$ ;
- the regulator always sets an access price  $p > 0$  that is below the unregulated monopoly price  $p_m$ . Hence, the level of access supplied in each period lies somewhere in the range  $q_{\max} > q > q_m$ , and the demand for access is always own price inelastic, as  $\pi'(q) < 0$ . The revenue flow in each period now decreases as the

access price falls, or alternatively decreases as the amount of access supplied rises;<sup>19</sup> and

- under FL cost regulation, the allowed revenue or net cash flow decreases at the same rate as the investment cost for a hypothetical efficient entrant to the industry at any given time  $t$ . This means, that the regulator allows the firm to earn a net cash flow  $\pi_{Ft}$ , where:

$$- \pi_{Ft} = \pi_{F1}(1 - \theta)^{t-1}, t = 1, 2 \dots T.$$

#### 5.4.2 Implications of The Model

Before proceeding to compare welfare under BL and FL cost regulation, it is necessary to establish two important implications that arise from the assumptions of the model. That is:

- (1) what does “consumer surplus” (i.e.  $CS(q)$ ) capture? and
- (2) how is welfare or efficiency in each period measured?

##### 5.4.2.1 The Meaning of “Consumer Surplus” in this Model

From the assumptions of the model, the investor supplies access to a single firm, which uses this access to produce a final product that it supplies to a single customer in the downstream retail market. Subsequently, what is referred to as the “demand curve for access” really represents a “derived demand curve”, which sums together the marginal value derived by the retailer and the customer on each unit of access that is supplied. Hence, what is referred to as “consumer surplus” here, will generally represent some combination of the profit to the retailer and the surplus derived by the downstream customer. However, there are specific instances when the demand curve for access may only capture either, the retailer’s profit, or the customer’s surplus.<sup>20</sup> For example:

- (1) **where there is perfectly elastic demand in the retail market**, the surplus derived by customers in the retail market is zero. What is referred to as “consumer surplus”, just measures the profit of the firm seeking access in the wholesale market; and

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<sup>19</sup> This is consistent with GSW, as in Assumption 3 (at page 6) they assume the net cash flow of the firm is increasing in price.

<sup>20</sup> It is well known that consumer surplus only provides a true measure of the welfare change if the income elasticity of demand for the good is zero. In such circumstances, there is no difference between the Marshallian and Hicksian demand curves.

- (2) **if the firm makes zero profit**, then “consumer surplus” in the demand curve only reflects the surplus that the downstream retail market customer derives as a result of the units of access supplied in the wholesale access market.

#### 5.4.2.2 Measuring Welfare

In the multi-period framework presented here, to maximise the total benefit derived by society from using the essential infrastructure over the  $T$  time periods, the level of social surplus in each period  $t = 1, 2, \dots, T$  must be maximised.

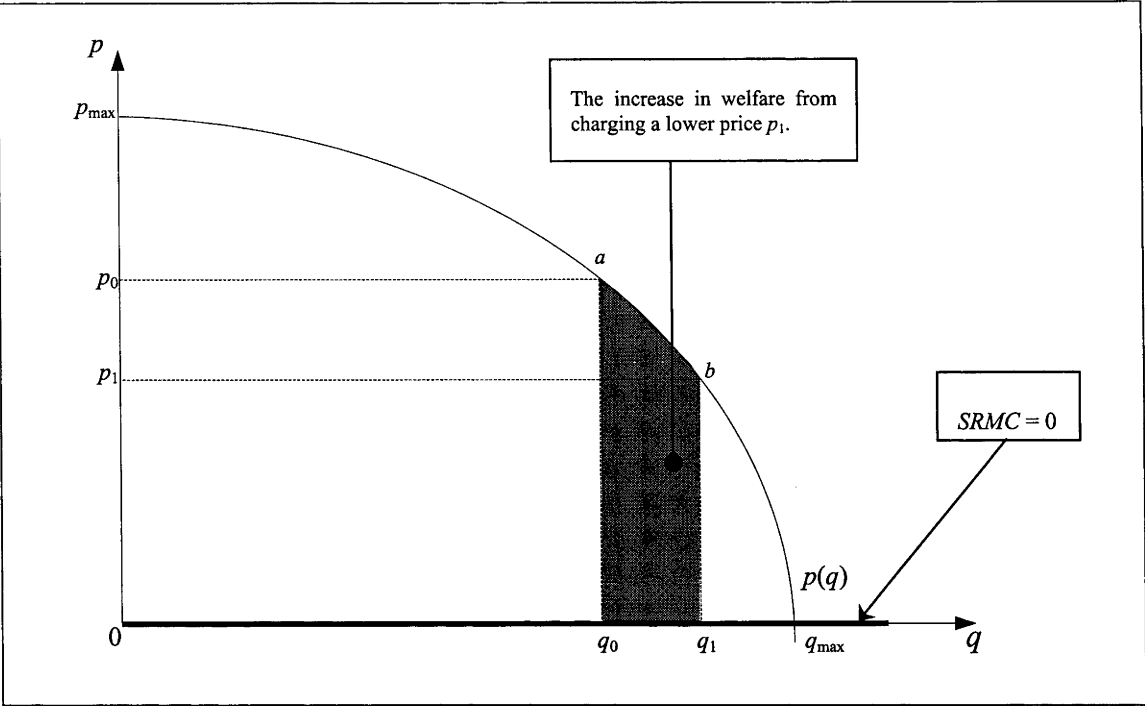
The social surplus in each period (i.e. short-run social surplus) is maximised, if short-run static allocative efficiency is achieved. This involves setting a price in each period, where the value to the consumer from the marginal unit of access — the marginal value — is equal to the cost to society of supplying the marginal unit — the marginal cost. As the short-run marginal cost of supplying access is by assumption zero (i.e.  $SRMC = 0$ ), a zero price, where  $q_{\max}$  units of access are supplied and consumed, maximises the level of social surplus in each period. Subsequently, the zero short-run-marginal-cost-based price forms the benchmark that must be used to assess the level of welfare that is derived in each period.<sup>21</sup> This is highlighted in Figure 5.4.1, where the zero short-run marginal cost is used to compare the level of welfare achieved in each period.<sup>22</sup>

Figure 5.4.1 depicts an outcome where price is decreased during a period from  $p_0$  — where  $q_0$  units of access are demanded — to  $p_1$  — where  $q_1$  units of access are demanded. The difference in welfare between the two prices involves comparing  $S(q_0) = \pi(q_0) + CS(q_0)$ , with  $S(q_1) = \pi(q_1) + CS(q_1)$ . In the diagram  $S(q_0)$  is equal to area  $p_{\max}ap_0$  plus area  $p_0aq_00$ , while  $S(q_1)$  is equal to area  $p_{\max}bp_1$  plus area  $p_1bq_10$ . Based upon these two areas, it is evident that the pricing regime  $p_1$  leads to a higher level of welfare, by an amount equal to the shaded area  $abq_1q_0$ . With the zero short-run marginal cost, this area represents the amount by which the total value derived by consumers on the units of access demanded  $q_0$  to  $q_1$ , exceeds the cost to society of supplying these additional units of access.

<sup>21</sup> Using short-run marginal costs as the basis for measuring welfare or undertaking static allocative efficiency analysis in each period, appears consistent with other work that uses multi-period models to assess optimal price regulation. For example, see Evans, Quigley and Zhang (2003).

<sup>22</sup> The reason why long-run marginal costs are not efficient in the framework used here, is that there is no long run in this model. Overall time is made up of a series of short-run time periods.

**FIGURE 5.4.1 COMPARING WELFARE OUTCOMES OF DIFFERENT REGIMES**



Understanding this simple example is important, as the comparison of BL and FL cost regulation done throughout this Section consistently involves using price-quantity diagrams and assessing areas such as  $abq_1q_0$  in Figure 5.4.1.

### 5.4.3 A Simple Welfare Comparison of BL and FL Cost Regulation

To conduct a simple welfare comparison between the constant BL cost-based and the decreasing FL cost-based price, it is initially assumed there are only three time periods — i.e.  $t = 0, 1, 2$  or  $T = 2$  — and there is a linear demand curve for access. While these appear to be restrictive assumptions, it is shown in Section 5.4.4, that the underlying results derived here, hold in a more general setting where  $T > 2$ , and there is a non-linear demand curve for access.

As it is assumed under both regimes the regulator allows the firm to earn a fair rate that generates a stream of net cash flows that recovers the original cost associated with the investment  $C_0$ , when  $T=2$ ,

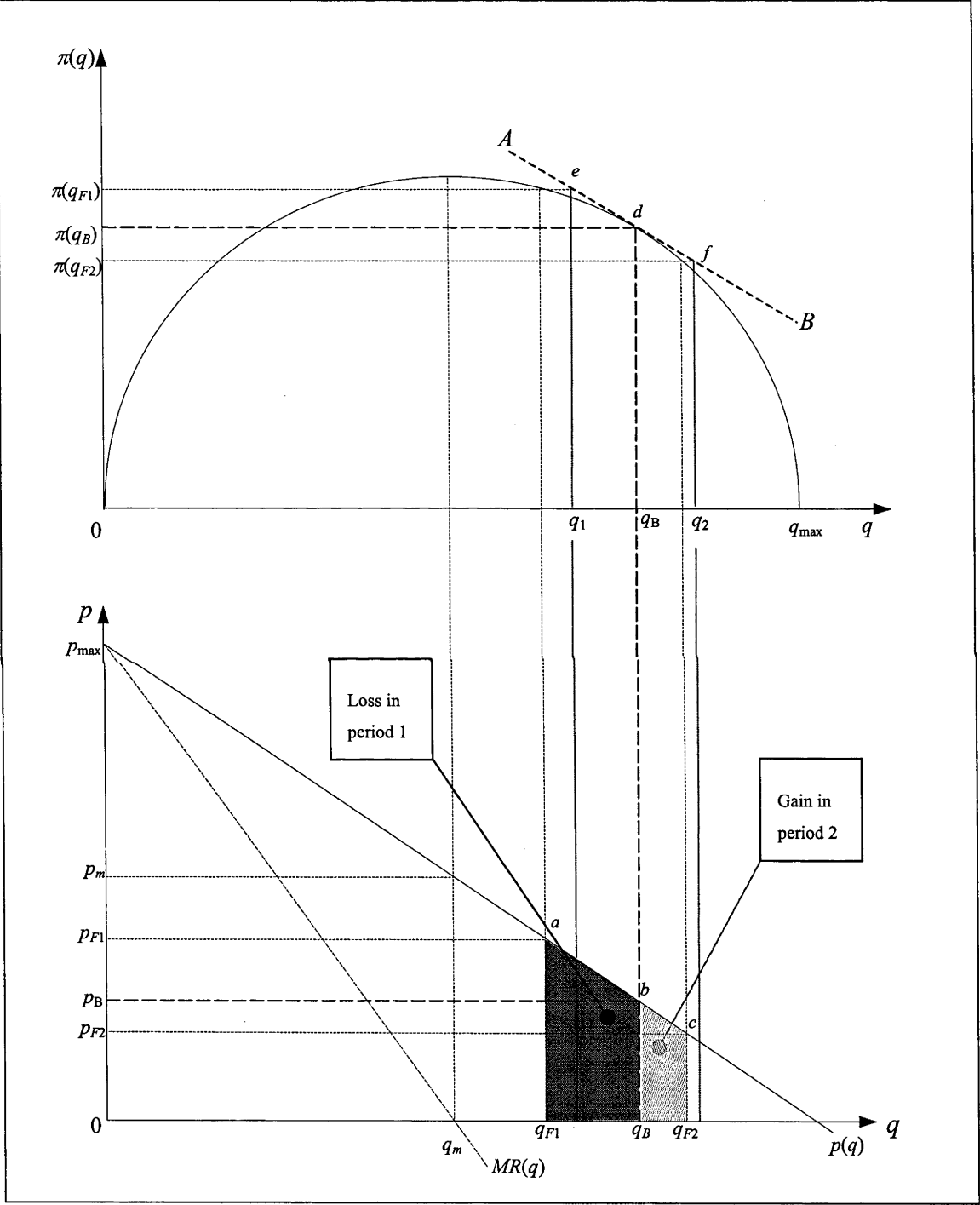
$$\pi_{F1} + \pi_{F2} = 2\pi_B = C_0 \tag{5.4.1}$$

Equation (5.4.1) can be rearranged to give,

$$\underbrace{\pi_{F1} - \pi_B}_{>0} = \underbrace{\pi_B - \pi_{F2}}_{>0} \tag{5.4.2}$$

This expression shows the familiar idea from Section 5.3, that in order to recover the cost associated with the investment, the FL cost-based net cash flow must initially be set higher and then below the constant BL cost-based net cash flow.

FIGURE 5.4.2 REVENUE AND WELFARE WITH LINEAR DEMAND FOR ACCESS



With a linear demand curve, as  $p''(q)$  is equal to 0, the second derivative for the net cash flow will be less than zero (i.e.  $\pi''(q) = 2p'(q) < 0$ ). Further, as regulation only takes place where the demand for access is own-price inelastic, as shown in Figure

5.4.2, the relevant region of the revenue function is characterised by a downward-sloping and strictly concave-shaped curve. Hence, the level of demand for access corresponding to the outcome in equation (5.4.2), has the property that,

$$\underbrace{q_B - q_{F1}}_{>0} > \underbrace{q_{F2} - q_B}_{>0} \quad (5.4.3)$$

The price-quantity diagram shows the result of adopting FL rather than BL cost regulation. The dark-shaded area corresponds to the welfare loss at time 1 —  $abq_Bq_{F1}$  — while a light-shaded area corresponds to the welfare gain at time 2 —  $bcq_{F2}q_B$ . Simple geometry can be used to establish that the size of this welfare loss, from using FL rather than BL cost regulation, exceeds the size of the welfare gain. That is, not only does the height of the area depicting the loss exceed the height of the area depicting the gain, but here, because of the condition satisfied in equation (5.4.3), the base of the area depicting the loss, also exceeds the base of the area depicting the welfare gain.

The difference between the two areas depicting the welfare loss and gain from using FL rather than BL costs, is also affected by the level of the cost-decreasing rate of technological progress  $\theta$ . The higher the rate of technological progress is here, the greater the amount by which welfare under BL cost regulation exceeds welfare under FL cost regulation. The reason for this is that with an increased rate of technological progress, the allowed level of revenue at time 1 —  $\pi_{F1}$  — will need to be set higher, while the allowed level of revenue at time 2 —  $\pi_{F2}$  — will need to be set lower. With a concave revenue function it follows that, when comparing FL cost regulation to BL cost regulation, the increase in the size of the welfare loss will be greater than the increase in the size of the welfare gain.

Therefore, in this simple example where  $T = 2$  and net cash flows are decreasing in the access price, BL cost regulation leads to a higher level of welfare than FL cost regulation, and this welfare superiority is greater, the higher the rate of technological progress is.

#### 5.4.4 A Welfare Comparison of BL and FL Cost Regulation

The previous sub-section established that BL cost regulation resulted in a higher level of welfare than FL cost regulation, when  $T = 2$  and there was a linear demand for access. This sub-section explores whether this outcome holds in a more general framework where  $T > 2$ , and where the demand for access is still own-price inelastic, but can be non-linear.

With  $T$  time periods both regimes lead to fully recovery of the costs associated with the investment,

$$\sum_{t=1}^T \pi_{Ft} = T \cdot \pi_B = C_0 \quad (5.4.4)$$

As in Section 5.4.2, this equation can be rearranged to give,

$$\underbrace{(\pi_{F1} - \pi_B)}_{>0} + \dots + \underbrace{(\pi_{Fk-1} - \pi_B)}_{>0} = \underbrace{(\pi_B - \pi_{Fk})}_{>0} + \dots + \underbrace{(\pi_B - \pi_{FT})}_{>0} \quad (5.4.5)$$

The LHS and RHS of Equation (5.4.5), separates the outcomes over the  $T$  periods, into two more general time periods. The first period, which is given by the expression on the LHS, denotes all those times  $t = 1, 2 \dots k-1$ , when the FL cost-based net cash flow exceeds the constant BL cost-based net cash flow. The second period, which is given by the expression on the RHS, denotes all those times  $t = k, k+1 \dots T$ , where the net cash flow under BL cost regulation is higher than the net cash flow earned under FL cost regulation.

#### 5.4.4.1 The Linear Net Cash Flow Function

As in Section 5.4.3, the regulator restricts the firm to operating in the inelastic portion of the demand curve. This implies  $\pi'(q) < 0$ , and that the net cash flow or revenue function is downward sloping. If it is initially assumed that the revenue function is also linear in quantity, the second derivative will be equal to zero (i.e.  $\pi''(q) = 0$ ). The difference between the net cash flows derived under BL and FL cost regulation in each period will then just be equal to some constant multiplied by the difference in quantity. Using  $\alpha$  to denote some constant that is less than zero (i.e.  $\alpha < 0$ ),

$$\alpha(q_{Ft} - q_B) = (\pi_{Ft} - \pi_B), t = 1, 2 \dots T \quad (5.4.6)$$

and it follows from equation (5.4.5) that,

$$\alpha(q_{F1} - q_B) + \dots + \alpha(q_{Fk-1} - q_B) = \alpha(q_B - q_{Fk}) + \dots + \alpha(q_B - q_{FT})$$

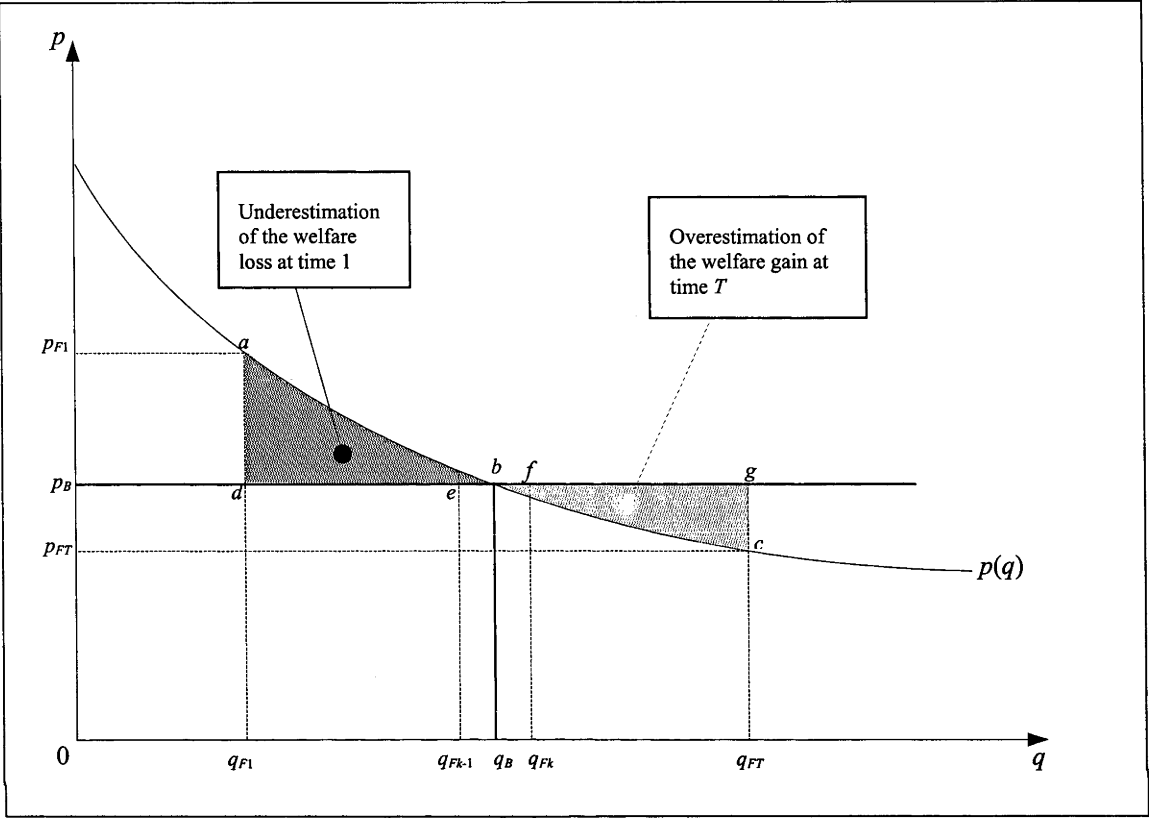
Dividing through by  $\alpha$  and rearranging the above expression yields

$$\underbrace{(q_B - q_{F1})}_{>0} + \dots + \underbrace{(q_B - q_{Fk-1})}_{>0} = \underbrace{(q_{Fk} - q_B)}_{>0} + \dots + \underbrace{(q_{FT} - q_B)}_{>0} \quad (5.4.7)$$

As it is possible to conduct welfare comparisons over changes in the level of output, equation (5.4.7) provides some insight into the welfare results during each period. The LHS of equation (5.4.7) shows all those times — time 1 to time  $k-1$  — where FL cost

regulation leads to a lower level of welfare than BL cost regulation. The RHS of equation (5.4.7) depicts all those times — time  $k$  to time  $T$  — where FL cost regulation leads to a higher level of welfare than BL cost regulation.

**FIGURE 5.4.3 WELFARE WITH A LINEAR REVENUE FUNCTION**



To examine whether the welfare gain from the increased supply of access in the later periods is sufficient to offset the size of the welfare loss that arises due to the under-supply of access in the earlier periods, equation (5.4.7) is multiplied through by the constant access price arising under BL cost regulation,  $p_B$ .

$$p_B [(q_B - q_{F1}) + \dots + (q_B - q_{Fk-1})] = p_B [(q_{Fk} - q_B) + \dots + (q_{FT} - q_B)] \quad (5.4.8)$$

The outcome in equation (5.4.8) is illustrated using the price-quantity space diagram of Figure 5.4.3.

From Figure 5.4.3, the LHS of equation (5.4.8) involves summing a sequence of areas that decreases over time, beginning at time  $t = 1$  with the area  $dbq_Bq_{F1}$ , and ending at time  $t = k - 1$  with the area  $ebq_Bq_{Fk-1}$ . The RHS of equation (5.4.8) involves summing a sequence of areas that increases over time, beginning at time  $k$  with the area  $bfq_{Fk}q_B$ , and ending at time  $T$  with the area  $bgq_{FT}q_B$ .



The diagram shows that the areas depicted by the LHS of equation (5.4.8), consistently under-estimate the welfare losses that arise in each period from using FL rather than BL cost regulation. For example, the first term in equation (5.4.8) —  $p_B(q_B - q_{F1})$  — under-estimates the welfare loss at time 1 by the dark-shaded area  $abd$ . In contrast, the areas depicted by the RHS of equation (5.4.8), consistently over-estimate the welfare gains resulting from using FL rather than BL cost regulation. The final term in equation (5.4.8) —  $p_B(q_{FT} - q_B)$  — over-estimates the welfare gain at time  $T$  by the lightly-shaded area  $bgc$ . Consequently, the sum of the welfare losses in each period ( $S_B - S_{Ft}$ ), where  $t = 1, 2 \dots k-1$ , exceeds the sum of the welfare gains in each period ( $S_{Ft} - S_B$ ), where  $t = k, k+1 \dots T$ , and the following condition is satisfied.

$$\underbrace{(S_B - S_{F1})}_{>0} + \dots + \underbrace{(S_B - S_{Fk-1})}_{>0} > \underbrace{(S_{Fk} - S_B)}_{>0} + \dots + \underbrace{(S_{FT} - S_B)}_{>0} \quad (5.4.9)$$

Alternatively, equation (5.4.9) can be rearranged to give,

$$T.S_B > \sum_{t=1}^T S_{Ft} \quad (5.4.10)$$

This expression indicates that with a linear downward-sloping revenue curve  $\pi(q)$ , BL cost regulation results in a greater benefit to society than FL cost regulation.

#### 5.4.4.2 Welfare with a Linear or Concave Demand Curve

The additional assumption made here is that the inverse demand curve for access  $p(q)$  has the property that  $p''(q) \leq 0$ . With a linear or concave demand curve, the sign of the second derivative of the revenue or net cash flow function will be less than zero (i.e.  $\pi''(q) < 0$ ). The resulting concavity of the revenue or net cash flow function means that here, the expression corresponding to equation (5.4.7), will now satisfy the condition,

$$\underbrace{(q_B - q_{F1})}_{>0} + \dots + \underbrace{(q_B - q_{Fk-1})}_{>0} > \underbrace{(q_{Fk} - q_B)}_{>0} + \dots + \underbrace{(q_{FT} - q_B)}_{>0} \quad (5.4.11)$$

Based on the analysis in Section 5.4.4.1, the result in equation (5.4.11) implies that compared to the outcome with a linear revenue curve, the size of the welfare losses from time 1 to  $k-1$ , now increase relative to the size of the welfare gains from time  $k$  to  $T$ . Therefore, the welfare superiority of constant BL cost-based price over the FL cost-based price that decreases over time will be greater with a linear or concave demand curve for access, and the inequality in equation (5.4.10) is once again satisfied here.

#### 5.4.4.3 A Positive Discount Rate and Technological Progress

With a positive constant discount rate or cost of capital  $r > 0$ , the regulator must ensure that under both regimes, the sum of the discounted net cash flows over the  $T$  time periods is equal to the original cost of the investment  $C_0$ .

$$\sum_{t=1}^T \frac{\pi_{Ft}}{(1+r)^t} = \pi_B \left[ \sum_{t=1}^T \frac{1}{(1+r)^t} \right] = C_0 \quad (5.4.12)$$

This translates to the condition,

$$\underbrace{\frac{\pi_{F1} - \pi_B}{(1+r)}}_{>0} + \dots + \underbrace{\frac{\pi_{Fk-1} - \pi_B}{(1+r)^{k-1}}}_{>0} = \underbrace{\frac{\pi_B - \pi_{Fk}}{(1+r)^k}}_{>0} + \dots + \underbrace{\frac{\pi_B - \pi_{FT}}{(1+r)^T}}_{>0} \quad (5.4.13)$$

By following the same methodology from the proofs done in the previous parts of this Section, it is also possible to establish here that with a positive discount rate,

$$S_B \left[ \sum_{t=1}^T \frac{1}{(1+r)^t} \right] > \sum_{t=1}^T \frac{S_{Ft}}{(1+r)^t} \quad (5.4.14)$$

Therefore, BL regulation leads to a higher level of welfare than FL cost regulation for any given discount rate  $r \geq 0$ .

Similar to the outcome observed in Section 5.4.3, a higher rate of technological progress here, results in the net cash flow allowed under FL cost regulation in period 1 increasing, and the net cash flow in the final period  $T$  decreasing. With a linear or concave revenue function, this increases the size of the welfare losses relative to the size of the welfare gains from using FL rather than BL cost regulation. All other things being equal, this increases the welfare superiority of the constant BL cost-based price over the FL cost-based price that decreases over time. Further, even if the rate of technological progress were uncertain, provided that it remains positive, it will result here in a monotonically-decreasing revenue or net cash flow function over time, which ensures BL cost regulation retains its superiority over FL cost regulation.<sup>23</sup>

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<sup>23</sup> Thank you to Vladimir Smirnov for pointing out this outcome.

#### 5.4.5 Can a Decreasing Price Over Time Increase Welfare?

The previous sub-sections illustrate cases where FL cost-based access prices that decrease over time, lead to lower levels of welfare than constant BL cost-based access prices that recover the same cost. The questions examined here are:

- will there be any situation when a decreasing price over time leads to a greater benefit to society than a constant price recovering the same cost? and
- if there is such a situation, does this indicate that with decreasing costs, when uncertainty and timing are ignored in the GSW model, it is possible for FL cost regulation to induce a better outcome for society?

For simplicity, to answer these questions, the assumptions about the own-price inelasticity of the demand for access are relaxed, and as in Section 5.4.3, it is assumed here that there is no discount rate and  $T = 2$ . As in all the previous analysis, the decreasing price over time is denoted here by the subscript  $Ft$ ,  $t = 0, 1, 2$  and the constant price charged is denoted by the subscript  $B$ .

From the earlier examples, it was evident that when comparing a decreasing price over time with a constant price, the height of the area for the welfare loss exceeded the height of the area for the welfare gain. Consequently, a decreasing price over time that recovers the same cost as a constant price over time, only induces a higher level of welfare if the difference in quantity in the second period ( $q_{F2} - q_B$ ), exceeds the difference in quantity in the first period ( $q_B - q_{F1}$ ). To achieve such an outcome there must be a convex demand curve, which generates a net cash flow function that is either:

- decreasing and convex in quantity (i.e.  $\pi'(q) < 0$  and  $\pi''(q) > 0$ );
- constant in quantity (i.e.  $\pi'(q) = 0$ ); or
- increasing in quantity (i.e.  $\pi'(q) > 0$ ).<sup>24</sup>

Figure 5.4.4 provides an example where a convex demand curve, i.e.  $p''(q) > 0$ , leads to a decreasing price over time that welfare dominates a constant access price. The diagram illustrates that when the slope of the demand curve changes rapidly from being very steep to very flat around the region of the relevant price change, the welfare loss in time 1 —  $abq_Bq_{F1}$  — is clearly less than the welfare gain arising in time 2 —  $bcq_{F2}q_B$ .

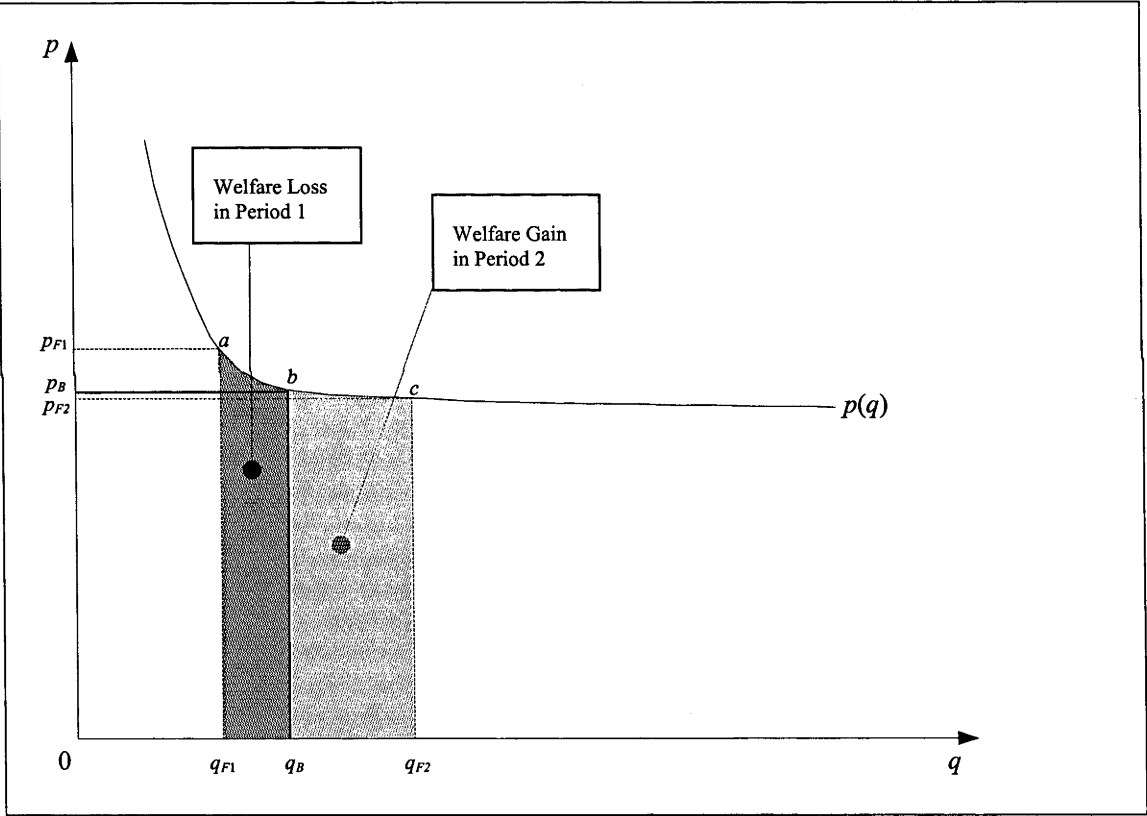
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<sup>24</sup> A convex demand curve may of course yield a decreasing and non-strictly convex revenue function. However, this will lead to outcomes that have been already been dealt with during the course of this Section.

This outcome suggests that, the more extreme the change in the slope of the demand curve, the greater the likelihood that a decreasing price leads to a higher level of welfare than a constant price that recovers cost.

The problem with having a convex demand curve that generates such net cash flow functions is that all are inconsistent with the net cash flow function used by GSW to compare BL and FL cost regulation.<sup>25</sup> Although GSW make no explicit assumptions about the demand for access, at Assumption 3 (at page 6) they do assume that the net cash flow of the firm is increasing and concave in the access price. In terms of the analysis here, this translates into a revenue function that is both decreasing and concave in the quantity of the access demanded i.e.  $\pi'(q) < 0$  and  $\pi''(q) < 0$ .

**FIGURE 5.4.4 A DECREASING PRICE RESULTING IN HIGHER WELFARE**



An additional problem with having a convex demand curve for access is that it can potentially lead to outcomes that contradict standard arguments made in access pricing

<sup>25</sup> GSW use the term “profit” to refer to the net cash flow. Their reference is slightly ambiguous, as they do not make it explicit that by profit they clearly mean the operating profit, rather than the economic profit of the firm.

disputes. Access providers have tended to automatically associate a decrease in the regulated access price with a decrease in the revenues they are allowed to earn. However, with a convex demand curve for access it is possible that the resulting net cash flow function may be increasing (or constant) in quantity. That is, a decrease in the price for access results in an increased (or unchanged) net cash flow. The reason for this is that around the region of the relevant price change, the demand for access is no longer always own-price inelastic, and the marginal revenue of production is now greater than (or equal to) zero. The access demand curve in Figure 5.4.4 illustrates such an outcome, as it is apparent that the revenue from charging the higher price  $p_{F1}$  —  $p_{F1}a_{F1}0$  — is less than revenue from charging the lower price  $p_{F2}$  —  $p_{F2}c_{F2}0$ . Consequently, when there is a downward drift in costs, to generate a stream of net cash flows that decreases at the same rate, the regulator must now allow the firm to charge a FL access price that is increasing over time (i.e.  $p_{F2}$  at time 1 and  $p_{F1}$  at time 2).

Therefore, even though it is possible for a decreasing price over time to induce greater benefit to society than a constant price recovering the same cost, it does not provide a justification for FL cost regulation when uncertainty and investment timing are ignored in the GSW model. The type of convex demand curve for access required to achieve such an outcome, violates the assumptions made by GSW about the net cash flow function. Further, a convex demand curve for access may yield outcomes that are inconsistent with the standard arguments raised in utility pricing disputes.

#### 5.4.6 Interpreting the Welfare Results of GSW

As outlined in the introduction of this Chapter in Section 5.1, GSW find that in their model, where both regimes recover the expected cost of the investment, the uncertain FL cost-based price that decreases over time, induces later investment in the essential infrastructure than the constant BL cost-based price. More significantly though, for the purposes of the analysis in this Section, their numerical examples highlight that with a downward drift in costs, BL rules also provide greater benefit to society. GSW attribute the welfare dominance of the constant BL cost-based access price to the later investment timing and the greater uncertainty that surrounds the downward-drifting FL cost-base price. However, the results established in this Section suggest that it is not necessary to appeal to uncertainty or investment timing to achieve such an outcome. Where there are decreasing costs over time and both schemes recover the cost of the investment, it is shown that a sufficient condition for the constant BL cost-based access

price to induce a greater benefit for society is that, the downward-sloping demand curve for access yields a non-convex net cash flow function that is decreasing in quantity.<sup>26</sup> The assumptions made by GSW about the net cash flow and total surplus to society, are consistent with having such an underlying demand curve for access.<sup>27</sup>

#### 5.4.7 Comparing Welfare using a Numerical Example

A numerical example is provided here to reinforce the welfare results that have been established during in the course of the Section. The expressions for net present value that is derived by society from having BL and FL cost regulation on the existing investment is,

$$NPV_{sB} = \sum_{t=1}^T \frac{S_B}{(1+r)^t} - C_0 = \sum_{t=1}^T \frac{CS_B}{(1+r)^t} \quad (5.4.15a)$$

$$NPV_{sF} = \sum_{t=1}^T \frac{S_{Ft}}{(1+r)^t} - C_0 = \sum_{t=1}^T \frac{CS_{Ft}}{(1+r)^t} \quad (5.4.15b)$$

Assuming there is a linear demand curve for access  $p(q) = a - b.q$ , where  $a, b > 0$ , the above equations are solved in the Appendix of the Chapter in Section A.5.1 and A.5.2, to yield the outcomes:

$$NPV_{sB} = \frac{1}{8b} \left( a + \sqrt{a^2 - \frac{4brC_0}{1 - (\frac{1}{1+r})^T}} \right)^2 \left[ \sum_{t=1}^T \frac{1}{(1+r)^t} \right] \quad (5.4.16a)$$

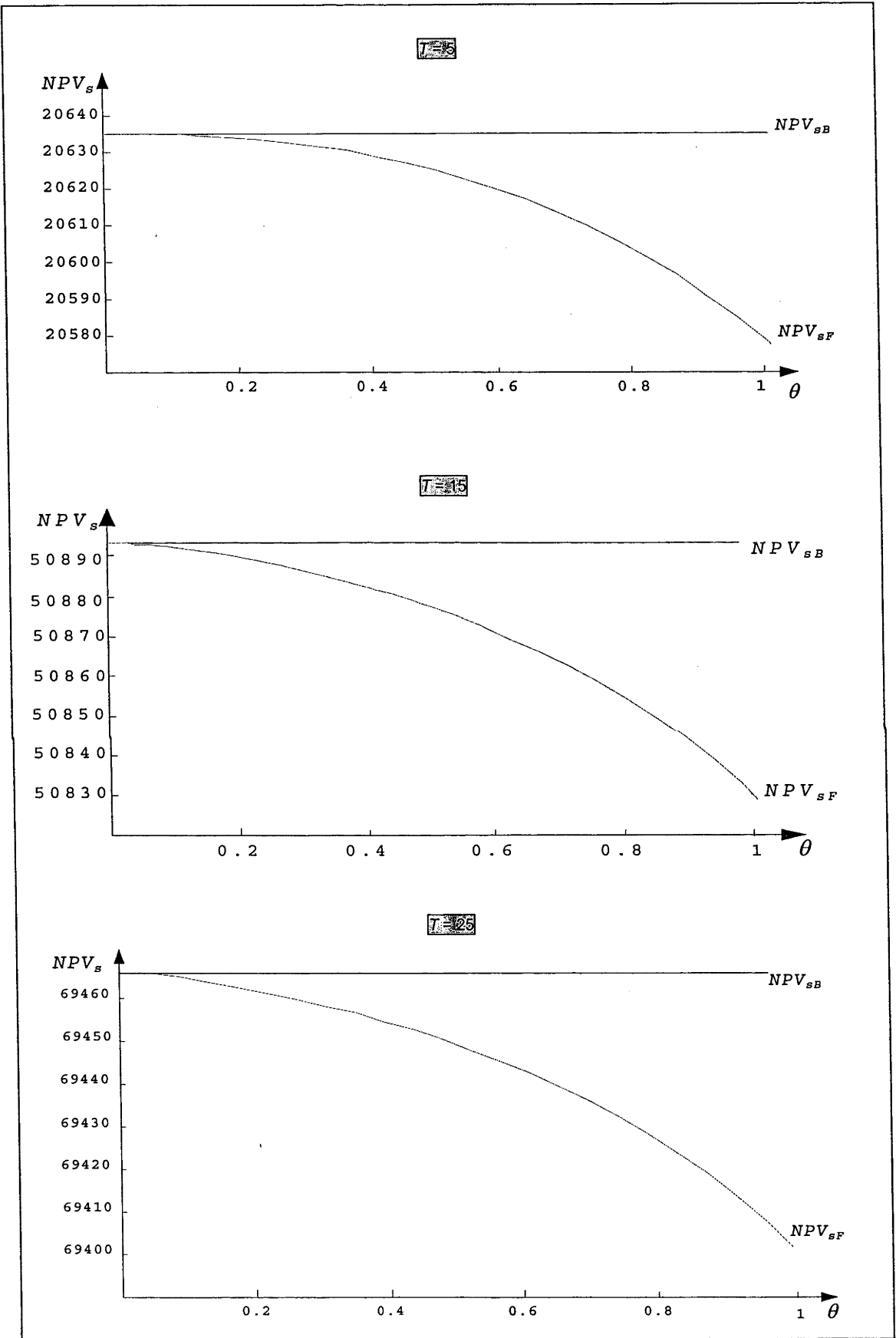
$$NPV_{sF} = \frac{1}{8b} \left[ \sum_{t=1}^T \frac{\left( a + \sqrt{a^2 - \frac{4b(\theta+r)C_0(1-\theta)^{t-1}}{1 - (\frac{1-\theta}{1+r})^T}} \right)^2}{(1+r)^t} \right] \quad (5.4.16b)$$

Assigning the values:  $T = 5, 15$  and  $25$ ;  $a = 10$  and  $b = 0.01$ ;  $C_0 = 1000$  and  $r = 0.05$ ; Figure 5.4.5 graphs the net present value to society for values of  $\theta$  between 0 and 1.

<sup>26</sup> As this is only a sufficient condition, there will be some class of convex demand curves that generates strictly convex revenue functions that also lead to the constant BL cost-based price inducing a higher welfare than the decreasing FL cost-based price.

<sup>27</sup> At Assumption 3 on page 6, it is assumed that the net cash flow is increasing and concave in the access price. Meanwhile, at Assumption 4 on page 6, it is assumed that the flow of total surplus to society is increasing in the access price. This implies society is better off if the access price is decreased, or conversely, the supply of access increased. Figure 5.4.2 and 5.4.3 illustrate that both these outcomes are satisfied with a linear demand curve for access.

FIGURE 5.4.5 GRAPHING  $NPV_s$ 's WITH  $T = 5, 15$  and  $25$



The results of the graphs are summarised in Table 5.4.1.

**TABLE 5.4.1 COMPARING THE NPV<sub>s</sub>'s FROM BL AND FL COST REGULATION**

<u><math>T = 5</math></u>				
$NPV_s \backslash \theta$	0.025	0.25	0.5	0.75
$NPV_{sB}$	20 635.27			
$NPV_{sF}$	20 635.25	20 633.2	20 625.3	20 608.7

<u><math>T = 15</math></u>				
$NPV_s \backslash \theta$	0.025	0.25	0.5	0.75
$NPV_{sB}$	50 893.37			
$NPV_{sF}$	50 893.32	50 888.5	50 877.3	50 859.7

<u><math>T = 25</math></u>				
$NPV_s \backslash \theta$	0.025	0.25	0.5	0.75
$NPV_{sB}$	69 466.12			
$NPV_{sF}$	69 466.02	69 460	69 448.7	69 431.1

The diagrams and tables confirm the results from this Section.<sup>28</sup> That is:

- a constant BL cost-based price cost leads to a greater benefit to society than a decreasing FL-cost based price when there is a positive discount rate;
- the higher the rate of technological progress is, the worse the outcome for society achieved by FL cost regulation. For very low levels of the rate of technological progress, the difference between the benefit to society from applying BL and FL cost regulation is minimal; and
- the longer the time period  $T$  is, the greater the amount by which welfare under BL exceeds the level of welfare achieved under FL cost regulation.

<sup>28</sup> The results in the graph and tables were also found to hold for a number of different values of  $r$ ,  $a$ ,  $b$  and  $C_0$ .



## 5.5 An Argument for Using FL Costs

While regulators have seen FL cost-based access prices as a means of supporting entry and investment by new competitors in recently deregulated markets, it has been highlighted that there appears to be little theoretical support for this view. This outcome appears to be reinforced by the result from Section 5.4. The analysis in this Section however, provides a theoretical justification for adopting FL costs. By using analysis similar to that of Crew and Kleindorfer (1992), it is shown that where a regulated firm is subject to competition at some future time period, FL cost regulation may provide the firm with compensation in instances where BL cost regulation fails to do so.

### 5.5.1 Crew and Kleindorfer (1992) — The Benefits of Accelerated Depreciation

Crew and Kleindorfer (1992) examines the problem of cost recovery when a rate-of-return (ROR) and price-cap (PC) regulated firm are subject to competition, in an industry experiencing a constant rate of cost-decreasing technological progress. They show that if competitive entry is allowed at some future time period, the regulator may only have a limited amount of time to increase the allowed cash flows to ensure that the incumbent can recover its costs. Crew and Kleindorfer refer to this limited time period as a “window of opportunity” (WOO). To increase the allowed cash flows in the initial periods, they suggest that the regulation should either increase the allowed market rate of return, or the allowed rate of capital recovery through accelerated or front-loaded depreciation. Accelerated depreciation works, by ensuring that the value of the asset is written down to a level that reflects its market value, at the time when the regulated firm is exposed to competitive market forces.

Crew and Kleindorfer outline that the higher the rate of technological progress is, and the greater the level of competition is, the smaller is the time period of the WOO. Consequently, to recover the cost of the investment in such circumstances, the regulator should employ a more accelerated depreciation schedule. This implies the choice of the depreciation pattern over time is now crucial for the regulated firm, and the invariance principle outlined by Schmalensee no longer holds. The authors though suggest that there will be some restricted class of depreciation schedules under the conditions of competition and technological progress that still allow the firm to recover its cost. They

refer to this as the “constrained invariance principle”, but maintain that these schedules must be significantly more accelerated than traditional straight-line methods.<sup>29</sup>

### 5.5.2 FL Cost Regulation and Competitive Entry

Section 5.3 illustrates that provided the depreciation rate is adjusted appropriately to account for the use of FL costs, then the firm earns a higher net cash flow in the earlier time periods. From the analysis of Crew and Kleindorfer it follows that, where the regulated industry is subject to future deregulation and entry, FL costs may provide the firm with cost recovery in instances where BL cost regulation does not. To highlight this advantage of FL cost regulation, the following example is outlined.

Adopting the framework outlined in Section 5.2, it is assumed here that the regulator initially employs either BL or FL cost regulation on the existing investment until some future period  $t_1$ . At this time, cost regulation of the firm ceases, and entry is allowed. If it assumed that there are many potential entrants with identical technology to the incumbent, then there will be a perfectly contestable market in the supply of the essential infrastructure. The access provider is subsequently restricted to earning a rate of return on cost  $C_t$ , where  $t \geq t_1$ , that is equal to the normal rate of return on capital  $r$ , plus the rate of economic depreciation on the asset  $\theta$ . This yields a net cash flow in each period of,

$$\pi_t = (\theta + r)C_t = (\theta + r)C_0 e^{-\theta t}, \quad t \geq t_1 \quad (5.5.1)$$

If the incumbent is initially subject to BL cost regulation prior to deregulation occurring, then over time the net cash flow will be,

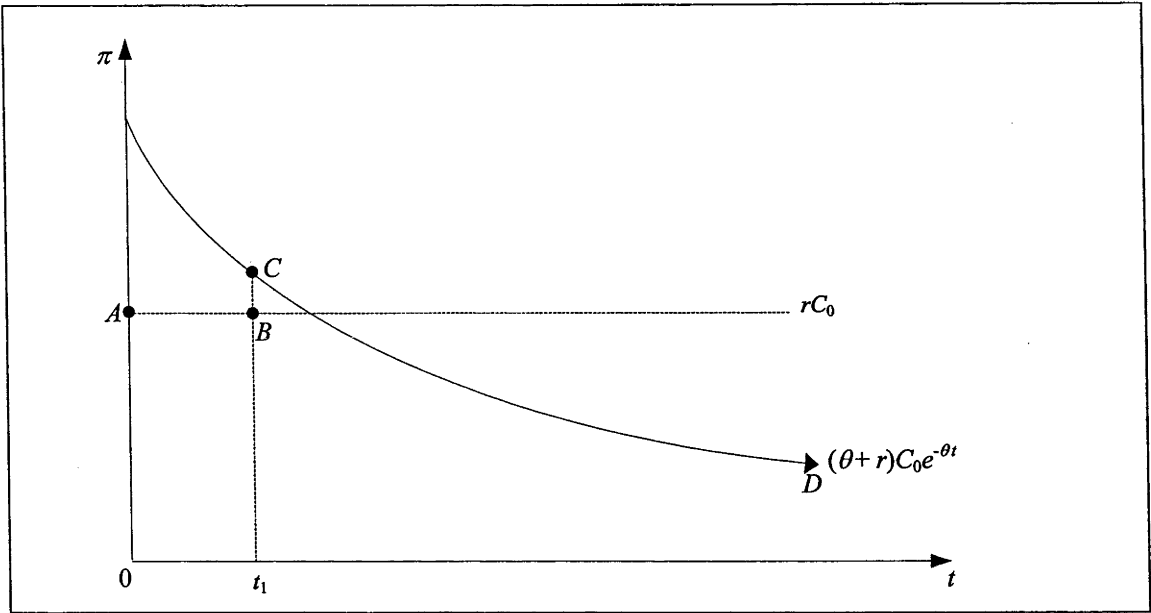
$$\pi_t = \begin{cases} rC_0 & , t < t_1 \\ (\theta + r)C_0 e^{-\theta t} & , t \geq t_1 \end{cases} \quad (5.5.2)$$

This pattern of cash flow follows the path  $AB-CD$  in Figure 5.5.1, and does not allow the firm to recover the cost of its investment as,

$$NPV_{JB} = \int_0^{t_1} rC_0 e^{-rt} dt + \int_{t_1}^{\infty} (\theta + r)C_0 e^{-\theta t} e^{-rt} dt - C_0 = \underbrace{C_0 e^{-rt_1}}_{>0} \underbrace{[e^{-\theta t_1} - 1]}_{<0} < 0 \quad (5.5.3)^{30}$$

<sup>29</sup> In contrast to Crew and Kleindorfer, Burness and Patrick (1992) finds that when there is no entry allowed in the industry, an accelerated depreciation rate leads to a lower level of welfare than a back-loaded depreciation schedule. For a good summary of the literature on depreciation for a regulated firm, see Hardin, Ergas and Small (1999).

FIGURE 5.5.1 NET CASH FLOWS BEFORE AND AFTER ENTRY



If the firm were instead subject to FL cost regulation prior to deregulation, then

$$\pi_t = (\theta + r)C_0 e^{-\theta t}, \forall t \geq 0 \quad (5.5.4)$$

In Figure 5.5.1, this net cash flow is illustrated by the curve  $(\theta + r)C_0 e^{-\theta t}$ . Unlike the BL cost regulation, the firm is able to cover its cost of capital as,

$$NPV_{\mathcal{F}} = \int_0^{\infty} (\theta + r)C_0 e^{-(\theta+r)t} dt - C_0 = C_0 - C_0 = 0 \quad (5.5.5)$$

In practice, unlike the situation described here, deregulation does often lead to entry taking place and a decrease in the level of demand that is served by the incumbent. In such circumstances, the post-deregulation earnings are less than  $(\theta + r)C_0 e^{-\theta t}$ , and the firm will incur a loss regardless of whether BL or FL costs is initially used by the regulator. However, as there is a smaller loss associated with the use of FL costs, it implies that compared to BL cost regulation, there will be less need to accelerate the depreciation schedule by as much to ensure that the incumbent access provider is fully compensated.

<sup>30</sup> The model used here also captures the outcomes that will arise if there is a transition from BL to FL cost regulation at time  $t_1$ . The outcome in equation (5.5.3) highlights the problem noted by Noam (2002) and Kahn et al. that in a transition from BL to FL cost regulation, the asset tends to be under-depreciated. In the example here, to recover the costs of the existing asset when there is a change in asset valuation at time  $t_1$ , the regulator would need to allow the previously BL cost-regulated firm to earn the higher fair rate of return  $(\theta + r)e^{\theta t_1} > (\theta + r)$ , or equivalently, the higher depreciation rate of  $(\theta + r)(e^{\theta t_1} - 1) + \theta > \theta$ .

## 5.6 Conclusion

This Chapter examined the impact of BL and FL cost regulation on an existing investment, in a model where it was assumed there was a constant exogenous rate of cost-decreasing technological progress, no uncertainty, and no incentive to pad costs.

The work here highlights that:

- to recover the cost of an existing investment where there are decreasing costs over time, a firm subject to FL cost regulation must be allowed to earn a higher fair rate of return than a firm subject to BL cost regulation. With no uncertainty, the most appropriate way to adjust the fair rate is to increase the allowed depreciation rate. This leads to the simple principle being established that in order to be fully compensated for the use of FL costs, the rate of decrease in the asset value by the regulator must be met by a corresponding increase in the allowed depreciation rate. The adjustment to the depreciation rate is a specific application of the “Invariance Proposition” highlighted by Schmalensee (1989).
- contrasting criticisms outlined in Chapter 4 that TELRIC/TSLRIC can under- or over-compensate the firm, both appear to rely upon the regulator failing to adjust the depreciation rate appropriately in the transition from BL to FL cost regulation. The only difference in the analysis of Holm (2000) — who argues that FL cost regulation can potentially over-compensate the firm — is that he examined a case where the FL costs of constructing the network had increased over time;
- it is not necessary to appeal to uncertainty or investment timing to generate findings in favour of BL cost regulation. By adopting basic assumptions similar to those used by GSW (2001), it is shown that a constant BL cost-based price will yield greater benefit to society than a FL cost-based price that is decreasing over time;
- the adoption of FL costs may be beneficial if the regulated firm is subject to competition in some future time period. Using analysis similar to that of Crew and Kleindorfer (1992), it is illustrated that provided the depreciation rate is appropriately adjusted to account for technological progress, then FL cost regulation may allow the investor to recover costs, in instances BL cost regulation fails to do so.

The basic framework used here is extended in the next two Chapters, which explores the impact of access regulation on investment timing. A comparison of investment timing under BL and FL costs is briefly considered in Chapter 7.

## A.5 Chapter 5 Appendix

### A.5.1 Deriving the Net Present Values to Society under BL in Equation (5.4.16a)

With discrete time under BL cost regulation, it is known that for an asset living  $T$  periods, the firm is allowed to earn a constant net cash flow of  $\pi_B$  that ensures,

$$NPV_{fB} = \sum_{t=1}^T \frac{\pi_B}{(1+r)^t} - C_0 = 0 \quad (\text{A5.1.1})$$

Solving this for  $\pi_B$  yields

$$\pi_B = \frac{rC_0}{1 - \left(\frac{1}{1+r}\right)^T} \quad (\text{A5.1.2})$$

With a linear demand curve for access  $p(q) = a - b \cdot q$ , where  $a, b > 0$ , equation (A5.1.2) can be simplified for an expression that is quadratic in the constant BL cost-based access price  $p_B$ .

$$p_B^2 - ap_B + \frac{brC_0}{1 - \left(\frac{1}{1+r}\right)^T} = 0$$

Applying the quadratic formula yields,

$$p_B = \frac{a \pm \sqrt{a^2 - 4 \left( \frac{brC_0}{1 - \left(\frac{1}{1+r}\right)^T} \right)}}{2}$$

As the price must be below the monopoly price  $p_m = a/2$ , only the minimum solution applies. The above expression can then be simplified to give a BL cost-based access price of

$$p_B = \frac{1}{2} \left( a - \sqrt{a^2 - \frac{4brC_0}{1 - \left(\frac{1}{1+r}\right)^T}} \right) \quad (\text{A5.1.3})$$

As the consumer surplus  $CS_B$  as a function of  $p_B$  is,

$$CS_B = \frac{(a - p_B)^2}{2b}$$

by substituting in for  $p_B$ ,  $CS_B$  can be solved to give,

$$CS_B = \frac{1}{8b} \left( a + \sqrt{a^2 - \frac{4brC_0}{1 - \left(\frac{1}{1+r}\right)^T}} \right)^2 \quad (\text{A5.1.4})$$

As in equation (5.4.15a) the expression for the net present value to society under BL cost regulation is,

$$NPV_{sB} = \sum_{t=1}^T \frac{CS_B}{(1+r)^t}$$

by substituting in the expression for  $CS_B$  in equation (A5.1.4), the following expression is derived.

$$NPV_{sB} = \frac{1}{8b} \left( a + \sqrt{a^2 - \frac{4brC_0}{1 - \left(\frac{1}{1+r}\right)^T}} \right)^2 \left[ \sum_{t=1}^T \frac{1}{(1+r)^t} \right]$$

This is outcome in equation (5.4.16a).

#### A.5.2 Deriving the NPV to Society under FL Cost Regulation in Equation (5.4.16b)

Under FL cost regulation, the net cash flow of the firm will decrease at the same rate as the FL costs. Therefore, where the net cash flow in the first period is some constant amount  $\pi_{F1}$ , the net cash flow at any time  $t$ ,  $\pi_{Ft}$ , will be equal to,

$$\pi_{Ft} = \pi_{F1} (1 - \theta)^{t-1}, \text{ where } t = 1, 2, \dots, T \quad (\text{A5.2.1})$$

Now for an asset living  $T$  periods, the firm is allowed to earn a FL cost-based net cash flow in each period  $t$ , that ensures,

$$NPV_{fB} = \sum_{t=1}^T \frac{\pi_{F1} (1 - \theta)^{t-1}}{(1+r)^t} - C_0 = 0 \quad (\text{A5.2.2})$$

Solving this for  $\pi_{F1}$  yields,

$$\pi_{F1} = \frac{(\theta + r)C_0}{1 - \left(\frac{1 - \theta}{1 + r}\right)^T} \quad (\text{A5.2.3})$$

or more generally, an expression for  $\pi_{Ft}$  of,

$$\pi_{Ft} = \frac{(\theta + r)C_0(1-\theta)^{t-1}}{1 - \left(\frac{1-\theta}{1+r}\right)^T}, \text{ where } t = 1, 2 \dots T \quad (\text{A5.2.4})$$

With a linear demand curve for access  $p(q) = a - b.q$ , where  $a, b > 0$ , equation (A5.2.4) can be simplified for an expression that is quadratic in the FL cost-based access price  $p_{Ft}$ .

$$p_{Ft}^2 - ap_{Ft} + \frac{b(\theta + r)C_0(1-\theta)^{t-1}}{1 - \left(\frac{1-\theta}{1+r}\right)^T} = 0$$

Applying the quadratic formula yields,

$$p_{Ft} = \frac{a \pm \sqrt{a^2 - 4 \left( \frac{b(\theta + r)C_0(1-\theta)^{t-1}}{1 - \left(\frac{1-\theta}{1+r}\right)^T} \right)}}{2}, \text{ where } t = 1, 2 \dots T$$

As the FL cost-based price must be below the monopoly price  $p_m = a/2$ , as with the BL cost-based price, only the minimum solution is taken. This yields a FL cost-based access price at any time  $t$  of

$$p_{Ft} = \frac{1}{2} \left( a - \sqrt{a^2 - \frac{4b(\theta + r)C_0(1-\theta)^{t-1}}{1 - \left(\frac{1-\theta}{1+r}\right)^T}} \right), \text{ where } t = 1, 2 \dots T \quad (\text{A5.2.5})$$

As the consumer surplus  $CS_{Ft}$  as a function of  $p_{Ft}$  is,

$$CS_{Ft} = \frac{(a - p_{Ft})^2}{2b}$$

$CS_{Ft}$  can be solved to give,

$$CS_{Ft} = \frac{\left( a - \sqrt{a^2 - \frac{4b(\theta + r)C_0(1-\theta)^{t-1}}{1 - \left(\frac{1-\theta}{1+r}\right)^T}} \right)^2}{8b}, \text{ where } t = 1, 2 \dots T \quad (\text{A5.2.6})$$

As in equation (5.4.15b) the expression for the net present value to society under FL cost regulation is,

$$NPV_{sF} = \sum_{t=1}^T \frac{CS_{Ft}}{(1+r)^t}$$

by substituting in for  $CS_{Ft}$  in equation (A5.2.6), the following expression is derived,

$$NPV_{sF} = \frac{1}{8b} \left[ \sum_{t=1}^T \frac{\left( a + \sqrt{a^2 - \frac{4b(\theta+r)C_0(1-\theta)^{t-1}}{1-\left(\frac{1-\theta}{1+r}\right)^T}} \right)^2}{(1+r)^t} \right]$$

This is the outcome in equation (5.4.16b).



# CHAPTER 6: ACCESS PRICING, INVESTMENT TIMING AND DYNAMIC EFFICIENCY

## 6.1 Introduction

Chapter 2 examined production efficiency under ROR regulation, while Chapter 3 assessed the allocative and production efficiency trade-off associated with the optimal fair rate. Chapter 5 compared the flows of short-run allocative efficiency derived over time, when the regulator applied different methods of asset valuation on an existing investment. This Chapter continues to analyse efficiency. It establishes a model that looks at impact regulation has on the investment timing or dynamic efficiency, and explores the potential for a static allocative and dynamic efficiency trade-off to arise.

### 6.1.1 The Importance of Dynamic Efficiency in Access Regulation

Traditionally, a great deal of commentary and formal analysis on public utility regulation has focused upon the effect regulation has on static allocative and production efficiency. While the concern over static efficiency outcomes remains, over the past decade there appears to have been increased emphasis placed on the impact regulation has on existing and future innovation and investment in infrastructure, or what has otherwise been referred to as “dynamic efficiency.” In Australia, this was reflected in the Hilmer Report (Independent Committee of Inquiry, 1993), which noted (at page 248) that if access regimes did not afford owners of essential infrastructure with “appropriate protection”, there was “the potential to undermine incentives for investment”.<sup>1</sup> More recently, the importance of dynamic efficiency has been highlighted in the separate Production Commission (PC) Inquiry Reports into the *Telecommunications Competition Regulation* (PC, 2001a) and the *National Access Regime* (PC, 2001b).

These reports outline the arguments raised by access providers, access seekers and regulators, in relation to the impact regulations have on current and future investment.

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<sup>1</sup> This is taken from PC (2001b) at page 66. It cites two passages from the Hilmer Report to emphasise what it describes as the “potential ‘chilling’ effect” access regulation can have on investment in essential facilities.

From this it appears that typically access providers assert that access regimes have been detrimental to investment, while access seekers and regulators maintain that there has been little, if any, adverse impact. In telecommunications, PC (2001a) shows (at pages 399-400) that Telstra has claimed that the access regime has reduced incentives to invest in the Public Switched Telephone Network (PSTN), and in the future could increase the risk associated with investment in digital technology. In contrast, the ACCC has argued that investment has not been damaged, and cites evidence that the nominal value of the network components associated with the PSTN has grown in aggregate by a trend rate of 6.4 per cent per annum from 1994-5 to 1999-00. In gas, PC (2001b) highlights (between pages 75-79) that access providers warned that as regulation offered no incentive to build pipelines with spare capacity, it had the potential to create a network of 'spaghetti pipelines', where pipelines were only built on the basis of what the market was contracted for at the time. ACCC and BHP Billiton concluded that there was no evidence of access regulation inhibiting investment, and the ACCC provided the example of the \$8 billion worth of new pipeline investments.

While the Productivity Commission appears to question the severity of the claims made by access providers, it does recognise that the access regime has the potential to have a significant impact upon current and future innovation and investment, or dynamic efficiency. For example, PC (2001a) outlines (at page 363, Box 11.1) that:

Excessively low access pricing reduces investment in bottleneck facilities. If uncorrected, this can lead to even more costly outcomes than higher prices because the infrastructure on which consumers depend may be sub-standard, delayed or not constructed at all.

and PC (2001b) takes the view (at page 67) that:

...the concerns about the *potential* for access regulation to deter investment appear to be well-founded. This in turn means that minimising the potential for such effects should be an important consideration in the design of access regimes.

In New Zealand, the importance of dynamic efficiency appears to have been even more strongly emphasised than in Australia. In a Commerce Commission (2001) discussion paper on access issues in telecommunications, it was held (at page 15, paragraph 70):

Where there are tensions between short term allocative efficiency and long term dynamic efficiency, the Commission takes the preliminary view that the later will generally better promote competition for the long term benefit of end user.

### 6.1.2 The Existing Literature on Investment Timing under Regulation

There has been a great deal of theoretical literature examining the static inefficiencies of rate-of-return (ROR) regulation and price-cap (PC) regulation of public utilities in both the wholesale access and the retail markets.<sup>2</sup> However, until recently, there appears to have been very little theoretical literature examining the impact access regimes have on investment timing in essential infrastructure and welfare. Gans has been involved in the majority of the recent work that has been done in this area. Examples of his work, includes, Gans and Williams (1999a), Gans (2001) and Gans and King (2002).<sup>3</sup>

Gans and Williams (GW, 1999a) examines access pricing and investment timing, where there are two firms competing to provide the infinitely-lived essential infrastructure, in an industry characterised by exponential decreasing costs over time, due to a constant rate of technological progress. Each firm decides if and when it should invest in infrastructure, in a situation where the investing firm becomes the access provider, while the other firm — provided it does not bypass the essential facility — becomes the access seeker. Further, it is assumed that the firms competing to undertake the investment do not engage in competition in the downstream market — i.e. the downstream market is non-rivalrous; and that there is no consumer surplus derived in the downstream market. In this framework it is shown that the firm has two motives for undertaking the investment. The first is based upon the firm's own willingness to pay for the infrastructure, while the other motive is based upon the firm's incentive to preempt the investment strategically. Examining the outcomes for a large and small firm, GW find that regulation of the fixed or lump sum access fee paid by the access provider, can induce the socially-optimal investment timing, and this result is generally independent of whether BL or FL costs are used to value the asset. The fixed fee for access they prescribe to achieve the socially-optimal timing of the investment, is a fully-distributed-cost-based (FDC) price, which is consistent with Lindahl pricing used in order to fund the provision of a public good.

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<sup>2</sup> Example of papers examining ROR regulation and price regulation in the retail market include Averch and Johnson (1962), Baumol and Klevorick (1970) and Armstrong, Cowan and Vickers (1994) Chapter 4. Examples of papers examining price and ROR regulation in the wholesale access market include Baumol and Sidak (1994), Armstrong, Cowan and Vickers (1996) and King (1997).

<sup>3</sup> Gans and Williams (1998) and Gans and Williams (1999b) also provide useful "primers" on the issue of the access charge and the timing of investment. These articles can be found at <http://www.mbs.unimelb.edu.au/jgans/research.htm>

Gans (2001) uses a certainty model similar to that of GW. Once again, there are two firms competing to undertake the investment, and there are the two motives for undertaking the investment — the firm's own willingness to pay and the incentive to pre-empt strategically. Significantly, the additional assumptions included are that the two firms now not only compete to undertake the investment, but also compete in the downstream retail market — i.e. the downstream retail market is rivalrous; and there is consumer surplus derived from consumption in the downstream retail market. Gans establishes that the optimal access pricing formula involves using a two-part tariff, where the usage price is set at the short-run marginal cost of providing access, and the fixed fee is based on a FDC-based price. While the majority of the analysis takes the usage charge as given and looks at the optimal fixed fee the regulator should set, Section 6 does consider the issue of the optimal usage price, and how the fixed charge should be adjusted to induce the socially-optimal investment timing.

Unlike the analysis of Gans and Williams (1999a), and Gans (2001), Gans and King (2002) examine investment timing where there is the issue of *ex ante* uncertainty over the value of the infrastructure. In particular, they examine the issue of truncation that may occur under regulation, and the impact this has on the investment timing of the firm. Gans and King conclude from their analysis that to avoid the problem of truncation, or what is sometimes referred to as the “asymmetric risk” arising from regulation, there may be scope for providing an investor with an “access holiday” — i.e. a period of time where it is not subject to any form of price regulation.

The papers by Guthrie, Small and Wright (GSW, 2001) and Evans and Guthrie (2002), use a real options approach to assess the issue of investment timing, and compare the impact BL and FL cost-based prices have upon welfare. They find that valuation of the asset does affect welfare, and both reach the general conclusion that, in industries experiencing more rapid rates of cost-decreasing technological progress, such as telecommunications, BL cost regulation should be employed, as it leads to a higher level of welfare.

In contrast to much of work done by Gans, GSW and Evans and Guthrie both examine the impact of a linear access price on investment timing. Their analysis subsequently captures some sort of short- and long-term efficiency trade-off. That is, as GSW note (at page 3), a “preferred access pricing scheme will match the marginal cost of bringing investment further forward in time (the lower total surplus resulting from raising access

charges) and the marginal benefit (earlier investment raises the present value of any given cash flow).”

Evans, Quigley and Zhang (EQZ, 2003), refers to the short- and long-term efficiency trade-off, as being between static allocative and dynamic efficiency. By adopting an endogenous growth model, their paper explores the optimal linear price monopolistic innovators should charge for the intermediate goods that are used to produce the final output in the economy. The model captures arguments raised by Schumpeter (1942) in relation to the need for transitory monopoly power, and establishes that; the optimal linear price that maximises the inter-temporal utility of consumers and recovers cost, lies above the short-run marginal cost of production and below the monopoly price. As the short-run marginal cost forms the basis for static allocative efficiency in their model, they refer to the resulting wholesale market price as a “second-best” price.

### 6.1.3 The Results and Contributions of this Chapter

This Chapter examines dynamic efficiency by establishing a model that looks at the investment timing when there is no uncertainty, a two-part access tariff, and a constant cost-decreasing rate of technological progress. Unlike the work of Gans, it is assumed potential investors can only invest in the infinitely-lived essential infrastructure, and cannot participate in any downstream retail market. Subsequently, there is no incentive strategically to pre-empt the investment. However, as the demand curve for access is responsive to changes in the usage price, as in GSW, Evans and Guthrie and EQZ, the model captures a static allocative and dynamic efficiency trade-off.

The model used in this and the following Chapter examines the two extreme market conditions of a:

- **monopoly investor** — a firm that has no competition to undertake the investment and therefore has an exclusive right to invest; and
- **competitive investor** — a firm that is subject to a perfectly-competitive market to provide the essential infrastructure, i.e. ‘competition to construct’.

In both situations it is assumed that after the investment has occurred, there is no additional entry to the access market.

By finding the properties of the dynamically-efficient time for any given access charge, the investment timing and benefits to society derived under the two extreme outcomes, is compared and assessed. Amongst other things; conditions are established when a competitive and monopoly investor is more likely to generate higher social benefits;

circumstances are outlined where there is a static and dynamic efficiency trade-off for an investor; it is found that ROR regulation of the monopoly investor has the same effect as having perfect competition to undertake the investment; and that as in Gans (2001), the socially-optimal outcome arises if the investor can charge a two-part access tariff. Further, throughout this Chapter, various concerns raised about access pricing and investment in the Productivity Commission reports — PC (2001a,b) — are incorporated into the analysis. In particular, it is shown that the work done here, and in following Chapter, is closely related to issues highlighted in Chapter 4 of PC (2001b), where the Commission considers the impact of access regulation on incentives to invest.

The Chapter is structured as follows. Section 6.2 establishes the model and contrasts investment timing by the monopoly and competitive investor. Section 6.3 defines dynamic efficiency, and uses this definition to show how at any given access charge, the net present value to society achieved by the monopoly and competitive investor, can be compared by examining investment timing. Section 6.4 outlines and then assesses claims made by academic and industry commentators, that the regulated access price involves a static allocative and dynamic efficiency trade-off. Section 6.5 explores the impact ROR regulation has on the monopoly investor, and highlights some equivalence results. Section 6.6 looks at the socially-optimal investment, and how the access charge must be set so that a competitive, ROR-regulated monopoly, and unregulated monopoly investor, will achieve this outcome. Section 6.7 concludes the analysis.

## 6.2 A Model of Investment Timing

This Section sets up the model that is used throughout the course of Chapter 6 and 7 to examine the issue of investment timing, and the benefit to society derived under various types of access regimes. The framework is used here to establish basic results for an investor that has an exclusive right to invest — a monopoly investor — and an investor that is subject to a perfectly-competitive market to provide the essential infrastructure — a competitive investor. It is shown that while a monopoly investor is able to achieve economic rents from providing the essential facility, a competitive investor invests earlier, and only earns a normal rate of return on the investment. Circumstances where an investor will hold a monopoly right to invest are also briefly considered.

### 6.2.1 Establishing the Model

#### 6.2.1.1 Assumptions of the Model

The framework employed to examine the issue of investment timing here, adopts a combination of the assumptions similar to those used in Section 5.2 and Section 5.4. The major difference is that, unlike Chapter 5, terms are now expressed as a function of the access price  $p$ , rather than the quantity of access demanded  $q$ , and the possibility of having a two-part access tariff is explored. To set up this model of investment timing, it is initially assumed for simplicity here that:

- there is continuous time  $t$ ;
- the cost to the firm and society of making the one-off-infinitely-lived investment at some time  $t$  is  $C_t$ ;
- the cost of undertaking the investment at time 0 is  $C_0$ ;
- there is some continuous exogenous rate of technological progress, so that the cost of undertaking the investment at any time  $t$ , is  $C_t = C_0 e^{-\theta t}$ ;<sup>4</sup>
- the opportunity cost of capital  $r > 0$ . As in Chapter 5 there is no uncertainty associated with the net cash flows, so this is equal to the risk-free rate;
- the asset does not physically deteriorate and there is no inflation in the industry;

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<sup>4</sup> Gans and Williams (1999a), Gans (2001), and Gans and King (2002), also adopt this assumption of a constant rate of technological progress.

- once the investment has been undertaken at some time  $t$ , a fixed amount of infrastructure is provided instantaneously;
- the facility has the capacity to supply the level of access demanded without the need for any additional investment;<sup>5</sup>
- no other firms supply the essential infrastructure, and the access provider does not compete in any related downstream market;<sup>6</sup>
- when the infrastructure is constructed there is instantaneous demand for access by a single firm. The access seeker uses access as an input and instantaneously provides a final product to a single customer in a downstream retail market;
- the demand curve for access is downward sloping (i.e.  $q'(p) < 0, \forall p > 0$ ), concave (i.e.  $q''(p) \leq 0, \forall p > 0$ ), and does not shift over time.<sup>7</sup> As in Chapter 5, the meaning of the “demand for access” where there is both a single retailer and downstream customer is explored in greater detail after all the assumptions have been made;
- there are no costs associated with the continued operations of the access provider after the investment in the infinitely-lived essential infrastructure has been made at time  $t$ . That is, the short-run marginal cost of supplying access at each instant is zero (i.e.  $SRMC = 0$ );
- if the investor charges a constant per-unit usage price  $p$  and fixed charge  $A$  for continued access, it would earn a constant net cash flow at each instant of  $\pi(p) + A$ ;
- where  $p_{\max}$  is the per-unit usage price when there is no demand for the essential facility (i.e. the “choke price”) and  $p_m$  is the monopoly price, revenue function  $\pi(p)$  has the following standard neo-classical properties:<sup>8</sup>
  - $\pi(0) = 0, \pi(p_{\max}) = 0$ ;
  - $\pi'(p) = p \cdot q'(p) + q(p)$ , where  $q'(p) < 0$ ;

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<sup>5</sup> This is the same as an assumption made by Gans (2001) that the natural monopoly has infinite capacity to supply access.

<sup>6</sup> This is different from the assumptions made in the work by Gans. His investment-timing models assume that firms compete to undertake the investment, and the ultimate investor becomes the access provider, while the firm that does not invest, becomes the access seeker. This allows him to assess strategic incentives to invest.

<sup>7</sup> Such an unchanged demand curve for access over time is implicitly used by GSW (2001).

<sup>8</sup> As there are no period-to-period operating costs, as in Chapter 5 the terms revenue, operating profit and net cash flow, can all be used interchangeably throughout the analysis in this and the following Chapter.



- $\pi(p_m) = \pi_{\max}$ , as at  $p_m$  the marginal revenue is equal to the short-run marginal cost of production (i.e.  $\pi'(p_m) = SRMC = 0$ );
  - $\pi'(p) < 0$  if  $p_{\max} > p > p_m$ ;
  - $\pi'(p) > 0$  if  $p_m > p > 0$ ; and
  - $\pi''(p) = 2q''(p) + q'(p) < 0$  as  $q'(p) < 0$  and  $q''(p) \leq 0$ ;
- for any combination  $(p, A)$ , the total benefit to the “consumer” from using the infrastructure at each instant is equal to the consumer surplus at the per-unit price  $CS(p)$ , minus the fixed fee  $A$  it is required to pay. That is, the total benefit is  $CS(p) - A$ , where the fixed fee is such that  $CS(p) \geq A$ . As in Chapter 5, the meaning of the term “consumer” is explored after all the assumptions of the model have been made;
- where  $CS_{\max}$  represents the maximum consumer surplus derived from the facility,  $CS(p)$  has the following properties:

- $CS(p_0) = \int_{p_0}^{p_{\max}} q(p)dp$ ;
- $CS(p_{\max}) = 0$ ,  $CS(0) = CS_{\max} > \pi_{\max}$ ;
- $CS'(p) = -q(p) < 0$ ,  $\forall p > 0$ ; and
- $CS''(p) = -q'(p) > 0$ ,  $\forall p > 0$ ;

- at each instant in time, the measure of the total welfare to society derived from the infrastructure  $S(p)$ , is equal to the sum of the total benefit to the user and the revenue to the access provider. That is,  $S(p) = CS(p) + \pi(p)$ ; and

- $S(p)$  has the properties:

- $S(p_{\max}) = 0$ ,  $S(0) = CS(0) = S_{\max} > \pi_{\max}$ ;
- $S'(p) = p \cdot q'(p) < 0$ ,  $\forall p > 0$ ; and
- $S''(p) = p \cdot q''(p) + q'(p) < 0$ ,  $\forall p > 0$ .

Although the framework established here appears to capture a retail-pricing problem, it can also be used to analyse the issue of access pricing.<sup>9</sup> As Chapter 5 illustrates, this can be done if the demand curve is interpreted as being a derived demand curve for

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<sup>9</sup> Analysing the access-pricing problem using a retail-pricing framework appears consistent with work done in various submissions to the PC inquiries, and the PC (2001a,b) reports. This particularly appears to be the case when the work focuses upon the impact that changes in the wholesale market access price will have on the level of welfare.

access. The term “consumer surplus” then represents some amalgam of the profit derived by the access seeker, and the benefit derived by the customer in the downstream retail market. Alternatively, to simplify the analysis further, similar assumptions to Section 5.4 can be adopted so that what is referred to as “consumer surplus” consists here of either, only the profit of the access seeker, or only the benefit derived by the retail market customer. For example, if:

- (1) **there is perfectly elastic demand in the retail market**, then regardless of the access price charged, consumer surplus in the retail market is zero. In that case the term “consumer surplus” measures the profits of the firm in the wholesale access market.
- (2) **the retail market firm earns zero profit**, then what is referred to as consumer surplus, actually represents the level of surplus derived by the customer in the downstream retail market.

#### 6.2.1.2 *The Value to the Firm of Undertaking the Investment*

The firm has an incentive to undertake the investment, as the earlier it invests, the earlier it realises the stream of revenue flows from its operations. As the essential infrastructure is infinitely lived, the stream of net cash flows goes on forever, and the payment derived from continually supplying access, is just equivalent to the payment received if the firm held a financial perpetuity. Thus, for the constant rate of return on similar risk-free assets  $r$ , and any per-unit usage price  $p$  and fixed fee  $A$ , the present value of the revenue flows derived by the firm investing at any time  $t$  is,

$$V_f(t, p, A) = \int_{\tau=t}^{\infty} \pi(p) e^{-r\tau} d\tau + \int_{\tau=t}^{\infty} A e^{-r\tau} d\tau = \frac{1}{r} (\pi(p) + A) e^{-rt} \quad (6.2.1)$$

#### 6.2.1.3 *The Value to Society of Undertaking the Investment*

The value of the investment to society is made up of; the present value derived by the access provider, and the present value of the benefits derived by the consumer. As with the access provider, the consumer benefits from the earlier provision of the facility. That is, the earlier the essential infrastructure is provided, the earlier the stream of benefits flow to the user. For any combination of the usage price  $p$  and fixed fee  $A$ , the discounted present value of total benefit to the consumer is,

$$V_c(t, p, A) = \int_{\tau=t}^{\infty} CS(p) e^{-r\tau} d\tau - \int_{\tau=t}^{\infty} A e^{-r\tau} d\tau = \frac{1}{r} (CS(p) - A) e^{-rt} \quad (6.2.2)$$

Adding together equation (6.2.1) and (6.2.2), the present value of the investment to society is,

$$V_s(t, p) = \frac{1}{r} (S(p)) e^{-rt}, \text{ where } S(p) = CS(p) + \pi(p) \quad (6.2.3)$$

#### 6.2.1.4 The Value to Society of Deferring the Investment

Although deferring the investment has the negative effect of delaying the realisation of the consumer surplus and operating profit, due to the cost-decreasing rate of technological progress  $\theta$ , it has the beneficial effect of decreasing the cost faced by the investor. As there are no external costs arising from the one-off investment, this is also the cost faced by society.

As the current cost of undertaking the one-off investment in infrastructure at any time  $t$  is just,

$$C_t = C_0 e^{-\theta t} \quad (6.2.4)$$

the present value of the discounted cost of the investment to society and the firm is,

$$C(t) = C_t e^{-rt} = (C_0 e^{-\theta t}) e^{-rt} = C_0 e^{-(\theta+r)t} \quad (6.2.5)$$

#### 6.2.1.5 The Net Present Value of the Investment to Society and the Firm

For the given usage price  $p$  and fixed fee  $A$ , the net present value of the investment to the firm,  $NPV_f$ , is found by subtracting the expression in equation (6.2.5) from the expression in equation (6.2.1) to give,

$$NPV_f(t, p, A) = V_f(t, p, A) - C(t) = \frac{1}{r} (\pi(p) + A) e^{-rt} - C_0 e^{-(\theta+r)t} \quad (6.2.6)$$

The overall level of welfare achieved from undertaking the investment, is given by the net present value to society,  $NPV_s$ . This is found by subtracting the expression in equation (6.2.5) from the expression in equation (6.2.3) to yield,

$$NPV_s(t, p) = V_s(t, p) - C(t) = \frac{1}{r} S(p) e^{-rt} - C_0 e^{-(\theta+r)t} \quad (6.2.7)$$

### 6.2.2 Investment Timing of a Monopoly Investor

A firm with an exclusive right to invest will provide the essential infrastructure at a time in the future that is most profitable for it. The firm is effectively a monopoly investor,

and for any given usage price  $p$  and fixed fee  $A$ , will invest at a time  $t_x$ , which maximises its net present value,  $NPV_f^x$ . That is,

$$\max_t NPV_f^x(t, p, A) = V_f(t, p, A) - C(t) \quad (6.2.8)$$

This yields the first-order condition (FOC),

$$\frac{dNPV_f^x}{dt} = -(\pi(p) + A)e^{-rt} + (\theta + r)C_0e^{-(\theta+r)t} = 0 \quad (6.2.9)$$

which can be solved for,

$$(\pi(p) + A) = (\theta + r)C_0e^{-\theta t_x} \quad (6.2.10)$$

This describes an outcome where the marginal benefit for the monopoly undertaking the investment, is equal to the marginal cost from investing at time  $t_x$ . The left-hand side of equation (6.2.10) denotes the marginal benefit, and is made up of the net cash flow earned by the firm at each instant once the investment is made. The right-hand side of equation (6.2.10) denotes the marginal cost to the firm at time  $t_x$ . This consists of the sum of the opportunity cost of capital  $r$  and capital loss from not deferring the investment  $\theta$ , multiplied by the cost of investing at time  $t_x$ . Another interpretation of equation (6.2.10) is found by dividing through by the cost of the investment at time  $t_x$ ,

$$\frac{(\pi(p) + A)}{C_0e^{-\theta t_x}} = \theta + r$$

This shows that a monopoly investor, charging any usage price  $p$  and fixed fee  $A$ , will maximise its net present value by investing in the facility at a time where it is able to earn a rate of return on the investment of  $\theta + r$ . Equation (6.2.10) can also be rearranged to provide an expression for the investment timing by the monopoly  $t_x(p, A)$ ,

$$t_x(p, A) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{\pi(p) + A} \right) \quad (6.2.11)$$

For any given usage price-fixed fee combination, the net present value to the firm and society is then found by substituting the expression for the investment time  $t_x(p, A)$  into equations (6.2.6) and (6.2.7).

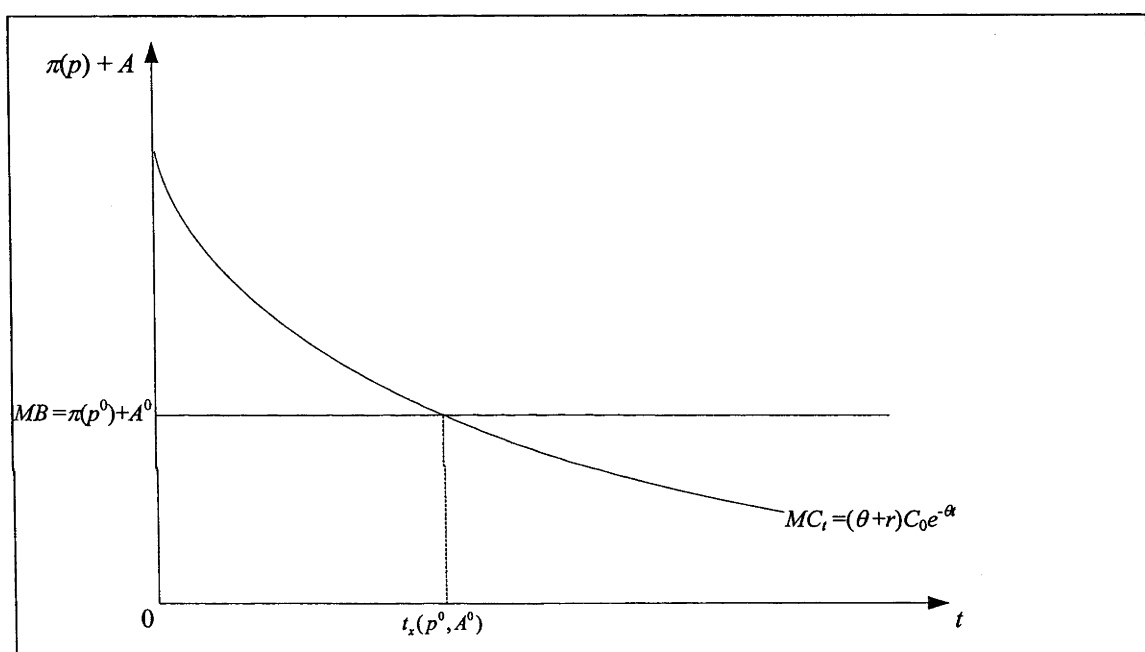
$$NPV_f^x(p, A) = \frac{1}{r} \left( \frac{\theta(\pi(p) + A)}{\theta + r} \right) \left( \frac{\pi(p) + A}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (6.2.12)$$

$$NPV_s^x(p, A) = \frac{1}{r} \left( \frac{\theta S(p) + r(CS(p) - A)}{\theta + r} \right) \left( \frac{\pi(p) + A}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (6.2.13)$$

The derivation for these expressions is found in the Appendix of Chapter 6 in Section A.6.1.

Assuming that the access charge consists of some usage price  $p^0$  and fixed fee  $A^0$ , the timing of the investment by a firm with a monopoly or exclusive right to invest, is illustrated in Figure 6.2.1.

**FIGURE 6.2.1 INVESTMENT TIMING WITH AN EXCLUSIVE RIGHT**



### 6.2.3 The Exclusive Right to Invest in Practice

In practice, an exclusive right to invest can arise either due to underlying market conditions in an industry, or restrictions placed on an industry by the government or regulator.

If in a market there is only one firm capable of undertaking the investment, it will hold an exclusive right to invest. This occurs if an industry is served by a monopoly. Alternatively where there are a number of potential investors, one firm can still effectively hold an exclusive right to invest, if it has a significant cost advantage over its rivals. For example, such an advantage could arise if, as the PC (2001a) states (at page 290), “the capacity to undertake the investment depends on some capability peculiar to a particular carrier”.

The government can create a monopoly investor by either passing legislation that prohibits entry and allows only one firm to service the entire industry, or as Dwyer and Lim (2001b) outline, by granting one firm an exclusive right to use easements. They suggest (at page 11) that:

Where by Crown grant of State action, a utility has privileged rights, such as easements or rights of way over the property others and any other would-be service provider does not enjoy similar rights, questions naturally arise about the lack of equality of access and lack of competition, inevitably raising in turn the questions of monopoly rents being charged to the public.<sup>10</sup>

If the government wishes to grant such a right yet also raise revenue, it may want to auction-off or tender-out the exclusive right to provide the essential facility.<sup>11</sup> In an extreme case where there is perfect competition to undertake the investment, tendering or auctioning-off the right to invest results in the entire present value of the economic rents derived by the monopoly investor being transferred lump-sum to the government. Therefore, although the monopoly investor earns a rate of return  $\theta + r$  in each period, after taking into account the amount that it pays the government to win this exclusive right, the net present value it derives from the investment will be equal to zero.

#### 6.2.4 Investment Timing with Competition

Where no firm is granted an exclusive right to invest, and there is perfect competition to undertake the investment, all potential rents are competed away. This type of outcome can arise when there are potential investors of identical cost competing to construct the essential infrastructure. It implies that, at any given usage price  $p$  and fixed fee  $A$ , the essential infrastructure will be provided at time  $t_o(p, A)$ , where the firm derives a net present value  $NPV_f^o$  of zero.

$$NPV_f^o(p, A) = \frac{1}{r}(\pi(p) + A)e^{-rt_o(p, A)} - C_0e^{-(\theta+r)t_o(p, A)} = 0 \quad (6.2.14)$$

---

<sup>10</sup> The PC (2001b) at pages 85-8, summarise the analysis of Dwyer and Lim (2001a,b), and recognise that an exclusive right to use easements may create monopoly rents. It also cites the above passage from Dwyer and Lim (2001b) in Box 4.3 at page 86.

<sup>11</sup> Chapter 5 and Chapter 11 (at pages 316-7) of PC (2001b) provide greater detail about the issue of the government tendering out services, franchising services, or auctioning off exclusive rights.

By rearranging the expression in equation (6.2.14), the condition can be restated in terms of the rate of return achieved by the investor. As opposed to a monopoly investor, who only invests when the rate of return  $\theta + r$  is achieved, a competitive investor, invests as soon as the given access charge allows it to earn the normal rate of return  $r$ .

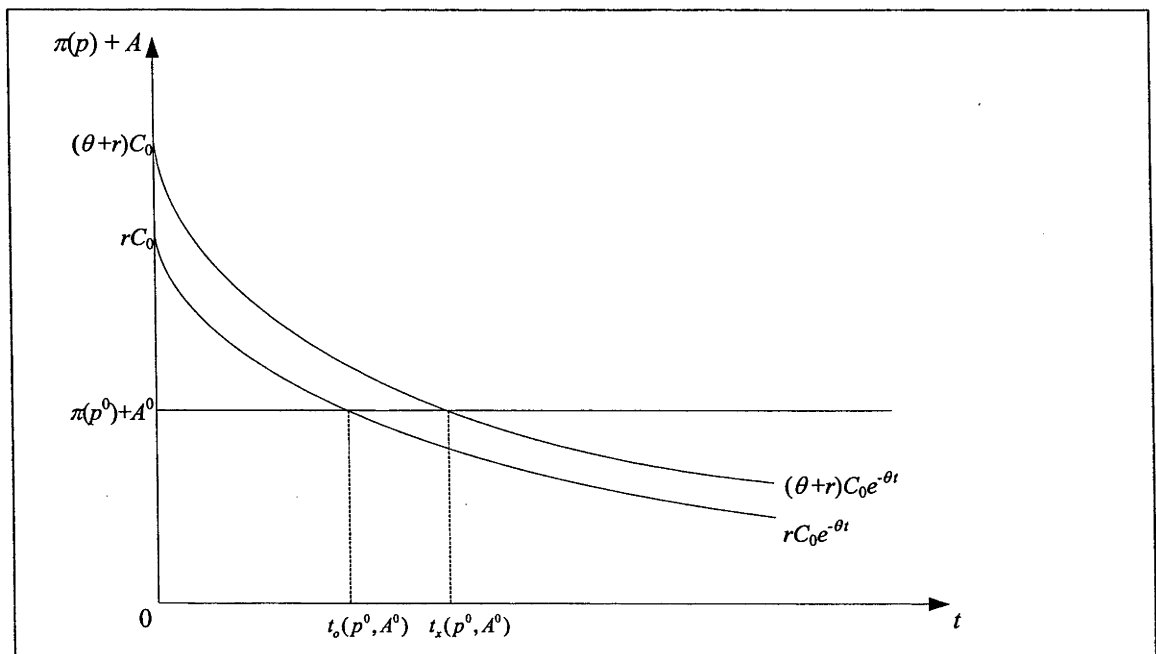
$$\frac{(\pi(p) + A)}{C_0 e^{-\theta t_0}} = r \quad (6.2.15)$$

This implies that, on the original cost of the investment, the term  $\theta$  captures the economic rent derived in each period by the monopoly. Further, for the same access charge it implies that, where there is the potential for competition to arise in providing the essential infrastructure, earlier investment timing is achieved by allowing competition to construct, rather than by granting one firm an exclusive right to invest (i.e.  $t_o(p, A) < t_x(p, A)$ ).

$$t_o(p, A) = \frac{1}{\theta} \log \left( \frac{r C_0}{\pi(p) + A} \right) < t_x(p, A) = \frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{\pi(p) + A} \right) \quad (6.2.16)$$

Assuming some given usage price  $p^0$  and fixed fee  $A^0$  is charged, the earlier investment timing by a firm subject to perfect competition is illustrated in Figure 6.2.2.

**FIGURE 6.2.2 INVESTMENT TIMING WITH COMPETITION**



The PC (2001b) recognises the potential for the outcome shown in Figure 6.2.2, when it suggests (at page 73, Box 4.2) that competition at the construction phase can lead to rent

dissipation “through bringing forward the timing of investment.” Further, in summarising the arguments of Dwyer and Lim (2001a,b), the PC outlines (at pages 85-6) that, where easements are free of charge and the project is competitive, other things being equal, it will bring forward the time at which the investment is undertaken.

When there is perfect competition to undertake the investment, the net present value derived by society when some usage price  $p$  and fixed fee  $A$  is charged, is found by substituting the expression for time  $t_o(p, A)$  into equation (6.2.7). This yields,

$$NPV_s^o(p, A) = \frac{1}{r} (CS(p) - A) \left( \frac{\pi(p) + A}{rC_0} \right)^{\frac{1}{\theta}} \quad (6.2.17)$$

The derivation of the outcome in equation (6.2.17) is outlined in the Appendix of this Chapter in Section A.6.2.



### 6.3 Dynamic Efficiency in the Model

As outlined in Chapter 4 and Section 6.1, dynamic efficiency has become a key issue in the debate over the appropriate regulated access charge. This Section analyses this issue of dynamic efficiency formally, by adopting a definition for the socially-optimal time, that is consistent with that used by the PC (2001b) and a number of analysts. By deriving an expression for the socially-optimal time  $t_w$ , properties of the socially-optimal time are examined. An important finding is that  $t_w$  changes in response to a change in the usage price  $p$ . In particular, the lower the usage price for access, the earlier is the dynamically-efficient time  $t_w$  for the investment. This subtlety appears to have been overlooked in the public policy analysis done in Australia. The definition for the socially-optimal time is also used to explore when a monopoly and competitive investor will be dynamically-efficient and inefficient at any given usage price  $p$  and fixed fee  $A$ . From this, a general conclusion is drawn as to when a competitive and monopoly investor will induce a better outcome for society.

#### 6.3.1 Defining the Dynamically-Efficient or Socially-Optimal Time

For a given usage price  $p$  and fixed fee  $A$ , in order to use the timing of an investment to assess whether one regime generates a higher net present value to society than another, it is necessary to have some notion of dynamic efficiency, or the socially-optimal time for the investment. The PC (2001b) outlines (at page 72) that it is reasonable to view it as “the time at which the net present value of an investment to the community — measured by the sum of producer surplus and consumer surplus — is maximised.” This definition of the socially-optimal time is consistent with that used by Gans (2001) and Evans and Guthrie (2002), and is adopted as the standard for dynamic efficiency throughout the course of this and the following Chapter.<sup>12</sup>

As from equation (6.2.7), the net present value to society at given the usage price  $p$  is,

$$NPV_s(t, p) = S(p)e^{-rt} - C_0e^{-(\theta+r)t}, \text{ where } S(p) = CS(p) + \pi(p)$$

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<sup>12</sup> For a slight variation on this definition for dynamic efficiency, see Evans, Quigley and Zhang (2003). As they adopt a framework traditionally used in endogenous growth models to assess the issue of optimal regulated access price, their definition involves maximising the inter-temporal utility of households.

the dynamically-efficient time for the investment to occur is found by taking the derivative with respect to time  $t$ , and setting the resulting expression equal to zero,

$$\frac{dNPV_s}{dt} = -S(p)e^{-rt} + (\theta + r)C_0e^{-(\theta+r)t} = 0 \quad (6.3.1)$$

Solving this, indicates that the essential infrastructure should be provided at a time  $t_w$ , where the social rate of return on the investment is  $\theta + r$ .

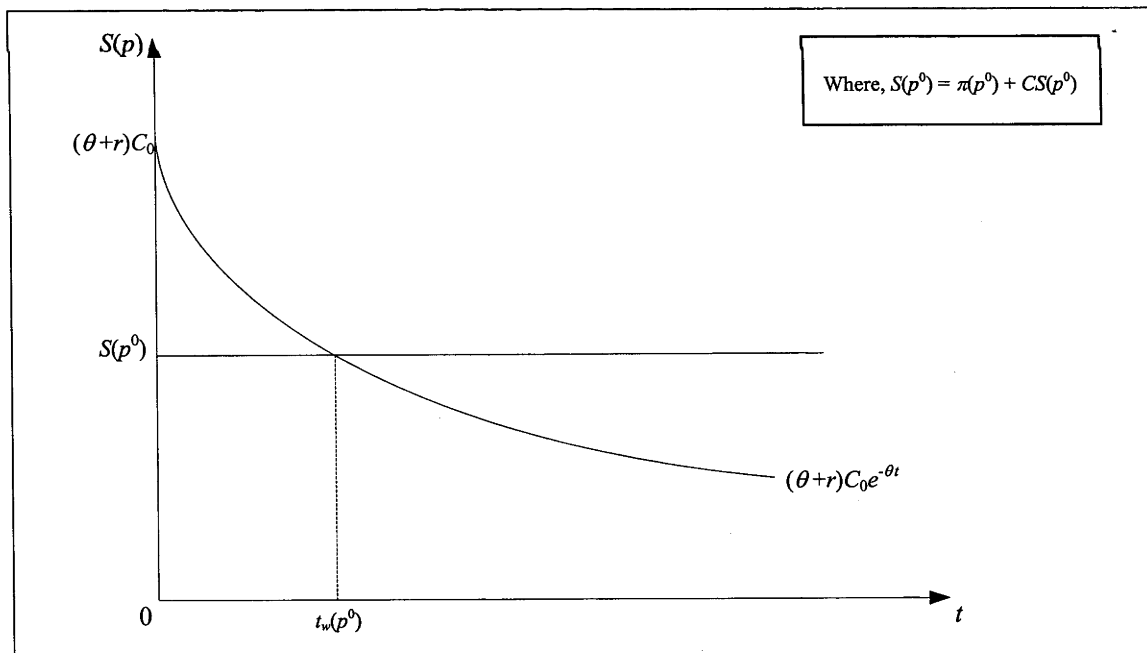
$$S(p) = (\theta + r)C_0e^{-\theta t_w} \quad (6.3.2)$$

Rearranging equation (6.3.2), the expression for the dynamically-efficient or socially-optimal time  $t_w$  associated with the given usage price  $p$  is,

$$t_w(p) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{S(p)} \right) \quad (6.3.3)$$

By assuming that the access tariff consists of some given usage price  $p^0$ , the dynamically-efficient time for the investment to occur at this price, is illustrated in Figure 6.3.1.

**FIGURE 6.3.1 THE DYNAMICALLY-EFFICIENT TIME**



Substituting the expression for  $t_w(p)$  into equation (6.2.7), the maximum net present value to society at any given usage price  $p$  is  $NPV_s^w$ , where

$$NPV_s^w(p) = \frac{1}{r} \left( \frac{\theta S(p)}{\theta + r} \right) \left( \frac{S(p)}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}, \text{ where } S(p) = \pi(p) + CS(p) \quad (6.3.4)$$

The derivation of the outcome in equation (6.3.4) is provided in the Appendix of this Chapter in Section A.6.3.

Dynamic inefficiency arises if the investment occurs at a time before or after  $t_w(p)$ . Investing too early is dynamically inefficient because, although the social surplus flows occur earlier, the cost to society of the investment is too high. Investing too late is dynamically inefficient because, although there is a benefit associated with having a lower cost of undertaking the investment, there is now too high a cost associated with foregoing social surplus for a number of periods.

As the important results for the monopoly investor, competitive investor and the social optimum at any given access charge  $(p, A)$  have now been established, for convenience, the respective outcomes are summarised in Table 6.3.1. These tabulated results are consistently referred to and used throughout the course of the Chapter to compare and assess the impact of various types of regulation.

**TABLE 6.3.1 KEY RESULTS AT ANY GIVEN ACCESS CHARGE  $(p, A)$**

	$t_i(p)$	$NPV_i^*$	$NPV_s^*$
Monopoly Investor ( $x$ )	$\frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{\pi(p) + A} \right)$	$\frac{1}{r} \left( \frac{\theta (\pi(p) + A)}{\theta + r} \right) \left( \frac{\pi(p) + A}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}$	$\frac{1}{r} \left( \frac{\theta S(p) + r(CS(p) - A)}{\theta + r} \right) \left( \frac{\pi(p) + A}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}$
Competitive Investor ( $o$ )	$\frac{1}{\theta} \log \left( \frac{r C_0}{\pi(p) + A} \right)$	0	$\frac{1}{r} (CS(p) - A) \left( \frac{\pi(p) + A}{r C_0} \right)^{\frac{r}{\theta}}$
Social Optimum ( $w$ )	$\frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{S(p)} \right)$	—	$\frac{1}{r} \left( \frac{\theta S(p)}{\theta + r} \right) \left( \frac{S(p)}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}$

### 6.3.2 Properties of the Dynamically-Efficient or Socially-Optimal Time

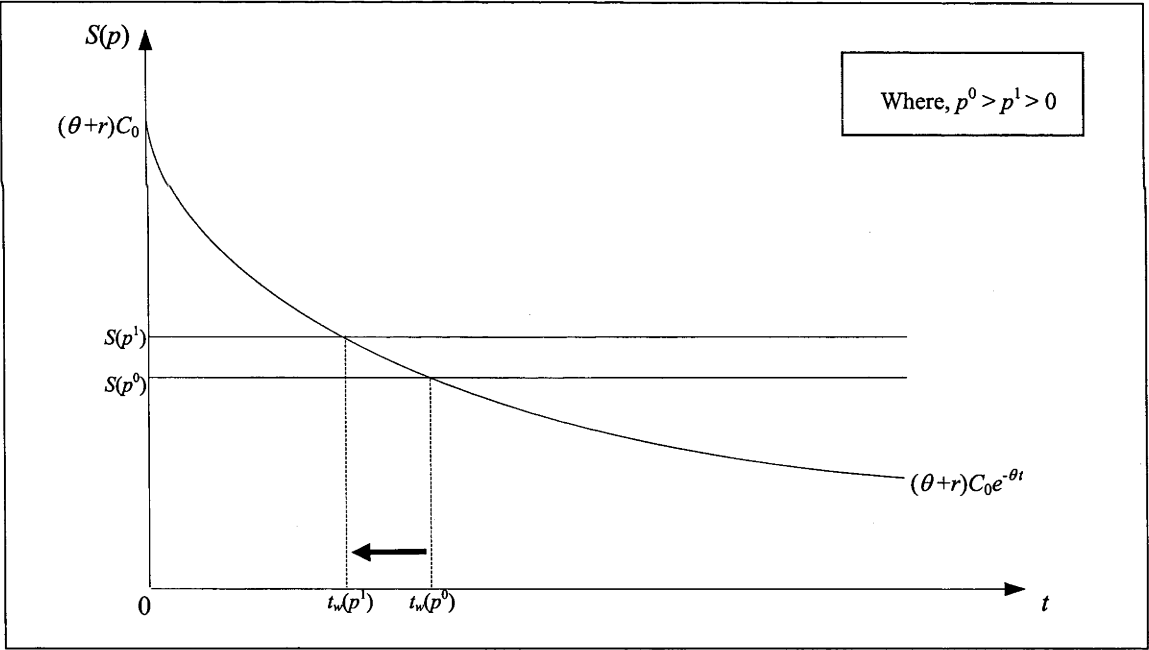
An implication of the definition for the socially-optimal time that does not appear to have been recognised in any of the submissions to, or final reports by the Productivity

Commission, is that it is non-unique and changes in response to a change in the usage price for access  $p$ .<sup>13,14</sup>

$$\frac{dt_w}{dp} = -\frac{1}{\theta} \frac{S'(p)}{S(p)} > 0 \tag{6.3.5}$$

The sign of equation (6.3.5) indicates that a decrease in the usage price for access  $p$ , leads to the dynamically-efficient time of the investment occurring earlier. The reason for this relationship between timing and the usage price is that, a decrease in the usage price increases the social surplus  $S(p)$  that flows in each period after the essential infrastructure has been provided. This increases the benefit relative to cost derived by society from undertaking the investment, and implies that the dynamically-efficient time associated with the lower price will be earlier. Assuming that the access tariff falls due to a decrease in the usage price from  $p^0$  to  $p^1$ , such a change in the socially-optimal time, can be illustrated in Figure 6.3.2.

**FIGURE 6.3.2 DYNAMIC EFFICIENCY WITH A CHANGE IN THE USAGE PRICE**



<sup>13</sup> A justification for the submissions and final reports ignoring this issue is that, all parties treated the demand curve as being perfectly inelastic. However, as all the analysis and diagrams in submissions and reports indicates that the quantity is responsive to the usage price  $p$ , it follows that this type of change in the socially-optimal time should have been considered.

<sup>14</sup> Gans (2001) assumes for the majority of his analysis that the usage price is given and set equal to the marginal cost of providing access. When Gans does adjust the usage price in Section 6, he looks at the effect this has on the strategic incentive to pre-empt, and analyses the impact this has on the level of the socially-optimal fixed fee that should be charged for access.

As a higher level of surplus is associated with the lower usage price, there must be a higher net present value to society associated with the earlier dynamically-efficient time  $t_w$ . To confirm this, the derivative of equation (6.3.4) is taken with respect to the usage price  $p$ , and the resulting expression is shown to be less than zero.

$$\frac{dNPV_s^w}{dp} = \frac{1}{r} \left( \frac{S(p)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} S'(p) < 0, \forall p > 0 \quad (6.3.6)$$

Therefore in Figure 6.3.2, the level of welfare achieved by investing at time  $t_w(p^1)$  will be higher than that achieved by investing at time  $t_w(p^0)$ .

### 6.3.3 Dynamic Efficiency with a Monopoly and Competitive Investor

Section 6.2 showed that for a given usage price  $p$  and fixed fee  $A$ , an investor subject to perfect competition, provided the essential infrastructure earlier than a monopoly investor (i.e.  $t_o(p, A) < t_x(p, A)$ ). The analysis in Section 6.3.1 suggests that, whether or not the earlier investment timing arising under competition will be beneficial, depends upon how close  $t_o(p, A)$  and  $t_x(p, A)$  are to the dynamically-efficient time  $t_w(p)$ .

#### 6.3.3.1 Achieving Dynamic Efficiency with a Monopoly Investor

Equating the expression for  $t_x(p, A)$  in equation (6.2.11), with the expression for  $t_x(p)$  in equation (6.3.3), a monopoly investor earning a rate of return on capital  $\theta + r$ , is dynamically efficient if at usage price  $p$ , it is allowed to charge a fixed fee  $A$  of,

$$A = CS(p) \quad (6.3.7)$$

This implies the monopoly investor achieves dynamic efficiency and maximises the net present value to society if it is able to internalise all the benefits to society derived from the investment, and earn a revenue flow in each period of  $S(p)$ .<sup>15</sup> In contrast, the earlier investment timing by the competitive investor is now dynamically inefficient.

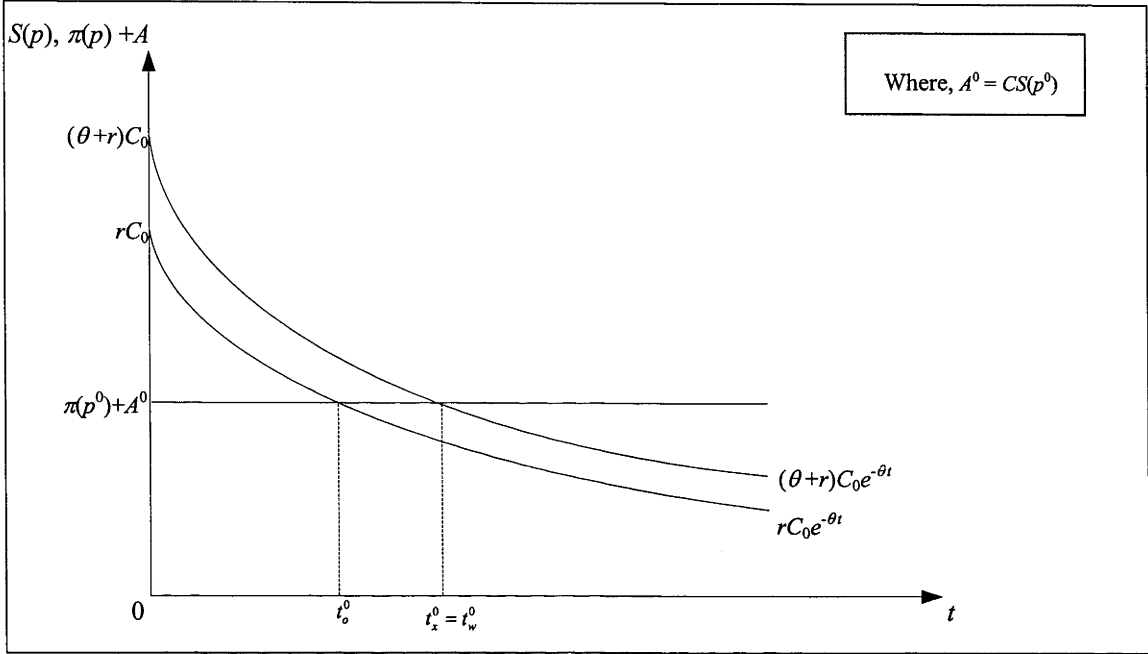
$$t_o(p, CS(p)) = \frac{1}{\theta} \log \left( \frac{rC_0}{S(p)} \right) < t_w(p) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{S(p)} \right) \quad (6.3.8)$$

By investing too early, the competitive investor incurs a cost to society that is too high, which leads to a net present value to society of zero. Assuming that the access tariff

<sup>15</sup> The PC (2001b) and Gans (2001) make a similar point.

consists of the given usage price  $p^0$  and fixed fee  $A^0 = CS(p^0)$ , and denoting the resulting monopoly, competitive and optimal investment timing with superscript 0, the outcome described here can be illustrated in Figure 6.3.3. The notation adopted for investment timing in this diagram is used throughout the remainder of this Chapter.

**FIGURE 6.3.3 ACHIEVING DYNAMIC EFFICIENCY WITH A MONOPOLY INVESTOR**



### 6.3.3.2 Achieving Dynamic Efficiency with a Competitive Investor

Equating the expression for  $t_o(p, A)$  in equation (6.2.16) with the expression for  $t_x(p)$  in equation (6.3.3), an investor subject to perfect competition to provide the essential infrastructure will be dynamically efficient, and maximise the net present value to society at any given usage price  $p$ , if the fixed fee charged satisfies the condition,

$$\frac{S(p)}{\pi(p) + A} = \frac{\theta + r}{r} \quad (6.3.9)$$

Substituting in for  $S(p)$  and simplifying, the above equation can also be expressed as,

$$\frac{CS(p) - A}{\pi(p) + A} = \frac{\theta}{r} \quad (6.3.10)$$

Rearranging, the expression derived for the dynamically-efficient fixed fee at the usage price  $p$  is,

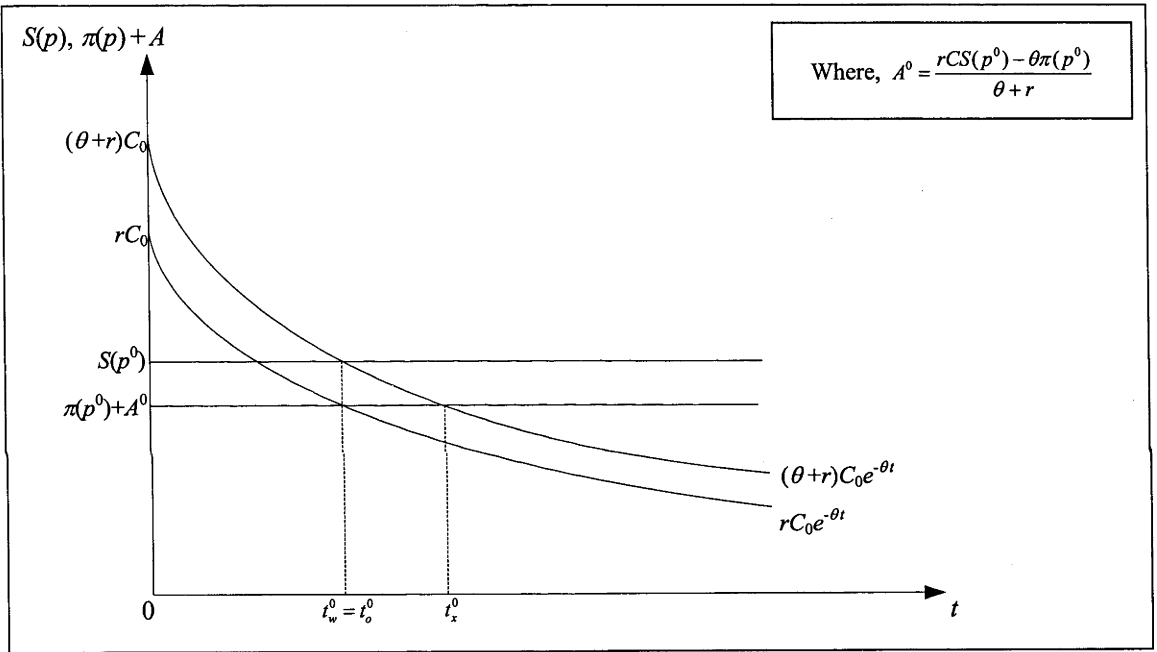
$$A = \frac{rCS(p) - \theta\pi(p)}{\theta + r} \quad (6.3.11)$$

This fixed fee induces the monopoly investor earning the return  $\theta + r$ , to inefficiently delay the investment, as it provides the essential infrastructure after the dynamically-efficient time  $t_w(p)$ . That is,

$$t_x(p, \frac{rCS(p) - \theta\pi(p)}{\theta + r}) = \frac{1}{\theta} \log \left( \frac{(\theta + r)^2 C_0}{rS(p)} \right) > t_w(p) \quad (6.3.12)$$

The outcome described here is illustrated in Figure 6.3.4, where the access tariff consists of the given usage price  $p^0$  and fixed fee  $A^0 = \frac{rCS(p^0) - \theta\pi(p^0)}{\theta + r}$ .

**FIGURE 6.3.4 ACHIEVING DYNAMIC EFFICIENCY UNDER COMPETITION**



From equation (6.3.11) it also apparent that the fixed fee that must be charged by the competitive investor to achieve dynamic efficiency, may either be greater than, less than, or equal to zero. More specifically, the dynamically-efficient fixed fee will be,

$$A = \begin{cases} > 0, & \text{if } \frac{CS(p)}{\pi(p)} > \frac{\theta}{r} \\ = 0, & \text{if } \frac{CS(p)}{\pi(p)} = \frac{\theta}{r} \\ < 0, & \text{if } \frac{CS(p)}{\pi(p)} < \frac{\theta}{r} \end{cases} \quad (6.3.13)$$

The intuition underlying these solutions is that, in the absence of a fixed fee, at the given usage price  $p$ :

- if  $CS(p)/\pi(p) > \theta/r$ , the competitive investor will inefficiently delay the investment. To ensure that the investment is undertaken earlier, and at the dynamically-efficient time  $t_w(p)$ , the fixed fee must be set greater than zero;
- if  $CS(p)/\pi(p) = \theta/r$ , the competitive investor will invest at the dynamically-efficient time, and no fixed access fee is required; and
- if  $CS(p)/\pi(p) < \theta/r$ , the competitive investor will undertake the investment too early. To ensure that the investment is deferred until the dynamically-efficient time  $t_w(p)$ , the fixed fee must be less than zero. That is, the competitive investor should be subject to some form of lump-sum tax.

### 6.3.3.3 The Dynamic Inefficiency of a Monopoly and Competitive Investor

The results of the previous two sub-sections imply that for any access charge  $(p, A)$ , if the fixed fee  $A$  is not set equal to  $CS(p)$  or  $\frac{rCS(p) - \theta\pi(p)}{\theta + r}$ , then neither the monopoly or competitive investor will be dynamically efficient. For such a dynamically-inefficient access charge, the monopoly investor always inefficiently delays the investment, while the competitive investor may either engage in inefficient delay or undertake the investment too early.

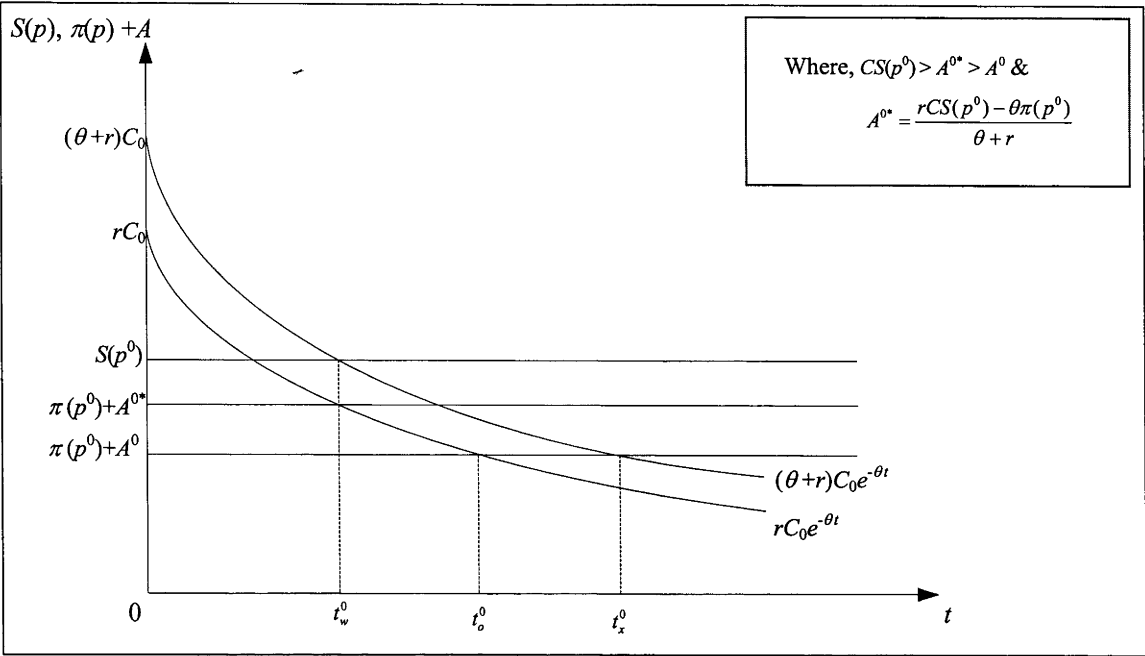
If the access charge  $(p, A)$  is such that,

$$\frac{rCS(p) - \theta\pi(p)}{\theta + r} > A \quad (6.3.14)$$

then both the monopoly and competitive investor inefficiently delay the investment. As the competitive investor always provides the essential infrastructure earlier than the monopoly investor, it follows that where both firms are engaging in inefficient delay, the competitive investor will be more dynamically efficient, and generate a higher net present value to society. To illustrate the outcome diagrammatically, it is assumed here that the access tariff consists of the given usage price  $p^0$  and fixed fee  $A^0$ , and that  $A^{0*}$  denotes the fixed fee that induces the competitive investor to provide the infrastructure at the dynamically-efficient time  $t_w^0$  (i.e.  $A^{0*} = \frac{rCS(p^0) - \theta\pi(p^0)}{\theta + r}$ ). All other things being equal, the result captured in Figure 6.3.5, is more likely to arise when there is a lower rate of technological progress and lower fixed fee for access.



FIGURE 6.3.5 DYNAMIC INEFFICIENCY RESULTING FROM DELAY

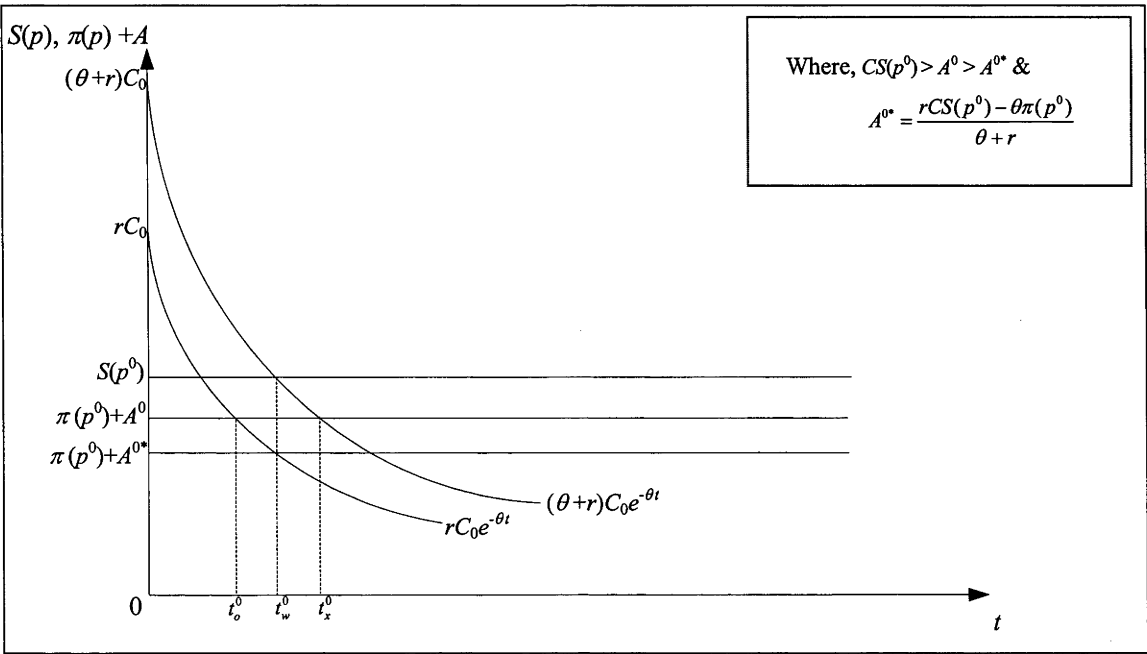


If the access charge  $(p, A)$  is such that,

$$CS(p) > A > \frac{rCS(p) - \theta\pi(p)}{\theta + r} \tag{6.3.15}$$

then the monopoly investor will inefficiently delay the investment, while the competitive investor undertakes the investment too early. Figure 6.3.6 illustrates such an outcome.

FIGURE 6.3.6 DYNAMIC INEFFICIENCY RESULTING FROM DELAY



In the circumstances described by equation (6.3.15) and illustrated in Figure 6.3.6, the monopoly investor may be more dynamically efficient, and generate a better outcome for society than the competitive investor. All other things being equal the condition in equation (6.3.15) is more likely to be met when there is a higher rate of technological progress and higher fixed fee.

From the results obtained in this Section the more general conclusion is reached that for any given access charge  $(p, A)$ , the competitive investor may only generate a worse outcome for society than the monopoly investor, if the competitive investor provides the essential infrastructure prior to the dynamically-efficient time  $t_w(p)$ .

## 6.4 The Static Allocative and Dynamic Efficiency Trade-Off

This Section initially establishes that in the framework used here, static allocative efficiency is achieved by setting the usage price equal to the short-run marginal cost of supplying access. It then outlines various claims made that the regulator faces a static allocative and dynamic efficiency trade-off when choosing the appropriate access price to set. That is, a lower access price leads to a higher level of static allocative efficiency, but decreases dynamic efficiency by reducing the incentive to invest. These claims are assessed in the model, by decreasing the access charge through a decrease in the fixed fee  $A$  and a decrease in the usage price  $p$ .

A decrease in the fixed fee  $A$  is found to only have an impact upon dynamic efficiency. Following on from Section 6.3, it is shown that it will decrease the dynamic efficiency of a monopoly investor, and can either increase or decrease the dynamic efficiency of a competitive investor. A decrease in the usage price though is shown to affect both investment timing and static allocative efficiency for the monopoly and competitive investor. Using the analysis from Section 6.3, it is illustrated that while there is a dynamic and allocative efficiency trade-off for the monopoly investor, a decrease in the usage price for access can potentially increase both dynamic and static allocative efficiency for the competitive investor. Regardless of whether there is an efficiency trade-off though, it is shown that for both investors, a decrease in the usage price will always generate a trade-off between:

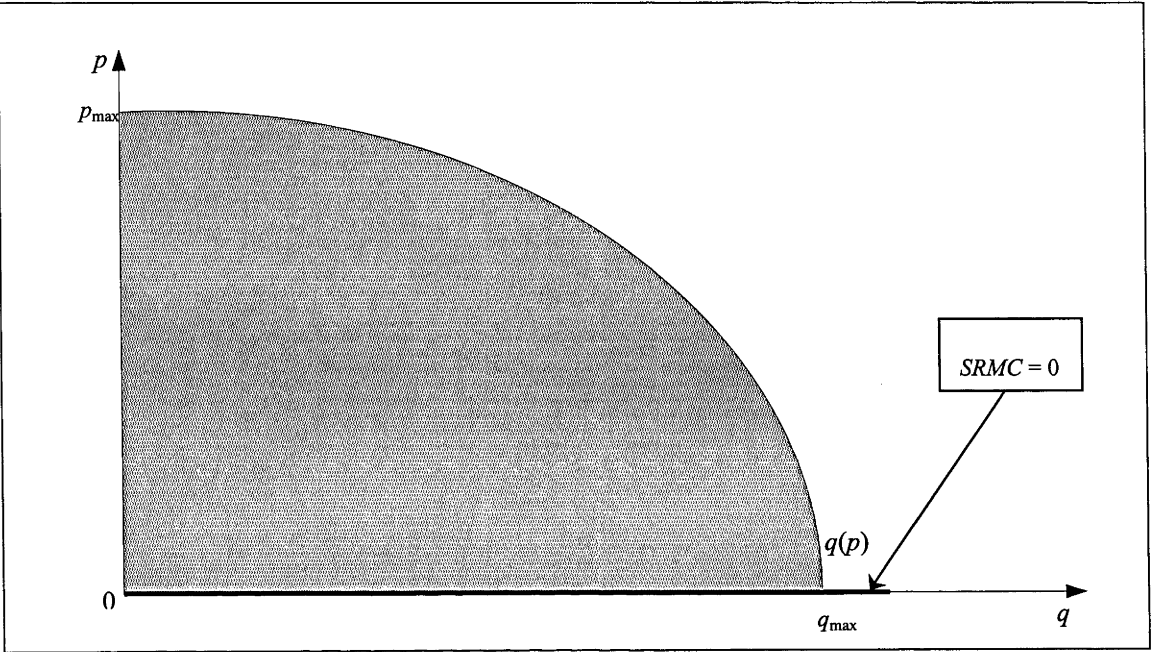
- **the additional benefit** from the lower cost and higher social surplus that arises once the investment is made; and
- **the additional cost** from deferring the investment and delaying the flow of social surplus until a later time.

### 6.4.1 Static Allocative Efficiency in the Model

Allocative efficiency is achieved in a market where the price reaches a level where the value derived by the consumer from the additional unit of output — the marginal value — is equal to the cost to society of supplying that extra unit — the marginal cost. In the framework used here, the level of demand and welfare are being assessed at each instant in time after the investment occurs. Hence, as in the model used in Section 5.4 of Chapter 5, the relevant timeframe for analysing allocative efficiency is the short run. Subsequently, static allocative efficiency is achieved by setting the usage price for

access equal to the short-run marginal cost of production, which by assumption from Section 6.2, is equal to zero (i.e.  $SRMC = 0$ ). The resulting surplus that flows to society at each instant from charging the static-allocatively-efficient-zero usage price once the investment has been made, is captured in Figure 6.4.1 by the shaded area  $p_{\max}q_{\max}0$ .

**FIGURE 6.4.1 SHORT-RUN STATIC ALLOCATIVE EFFICIENCY**



Using short-run marginal cost as the benchmark for static allocative efficiency is consistent with the work done by Evans, Quigley and Zhang (EQZ, 2003), which examines the optimal regulated price in a model where there is a static and dynamic efficiency trade-off.

### 6.4.2 Claims of an Efficiency Trade-Off

Although concerns over static allocative efficiency remain central to the debates over the appropriateness of the regulated access price, as alluded to in the introduction of this Chapter, there has gradually been a greater emphasis placed on the incentives such prices create for future investment and innovation i.e. “dynamic efficiency”. In particular, certain regulatory authorities, and academic and industry commentators, have highlighted that the regulated access price may involve a static allocative and dynamic efficiency trade-off. Various references that have been made to this trade-off are summarised in the analysis that follows.

King and Maddock (1996) note (at page 106) that, “the pursuit of short-term efficiency may become detrimental if it results in long-term inefficiencies.” In the following

sentence they warn if, “regulations designed to promote the ‘correct’ prices today dissuade investors from building new infrastructure tomorrow, then the long-term dynamic costs of the regulation can easily outweigh the transitory benefits.” Therefore in setting the optimal regulated access price, King and Maddock maintain (at page 107):

The regulatory authorities will inevitably find themselves trading off short- and long-term goals. At best, a balance will be struck between those goals which provides reasonable benefits to both present and future consumers.

However, the authors also recognise the difficulty faced by the regulator in setting the optimal regulated access price, as they conclude (at page 122), “the trade-off between static and dynamic efficiency allows for few simple answers.”

In submissions to the Productivity Commission inquiry into the National Access Regime, Network Economic Consultancy Group (NECG) has consistently argued that the regulator should consider the static allocative and dynamic efficiency trade-off, when setting the regulated access price.<sup>16</sup> NECG (2001a) states (at page 16) that:

...regulators effectively face a choice between (i) erring on the side of lower access prices and seeking to ensure they remove any potential for monopoly rents and the consequent allocative inefficiencies from the system; or (ii) allowing higher access prices so as to ensure that sufficient incentives for efficient investment are retained, with the consequent productive and dynamic efficiencies such investment engenders.<sup>17</sup>

In a later submission NECG (2001b) repeats the same line of reasoning, when it suggests (at page 13) that the Productivity Commission:

...needs to undertake a careful cost-benefit analysis to ensure that their final recommendations maximise dynamic efficiency gains, with the minimum possible costs in terms of allocative efficiency.

The PC (2001b) cites the passage from NECG (2001a) at page 83, yet appears to reject the notion that there exists such a simple efficiency trade-off. It states that it:

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<sup>16</sup> For an opposing view, see the passage from the submission by BHP Billiton that is cited by the PC (2001b) at page 127, which states that:

It is not established that there is an inherent conflict between static and dynamic efficiency or that monopoly pricing is necessary to induce investment in infrastructure.

<sup>17</sup> NECG (2001a) go on to analyse allocative efficiency in the short- and long-run at pages 21 and 23. However, its analysis of allocative efficiency is incorrect, as it does not assume constant-returns-to-scale technology, yet uses short-run and long-run average cost curves, rather than the appropriate short- and long-run marginal cost curves to assess welfare in the industry. It also does not use a model to address the issue of investment timing formally in its submission.

...does not subscribe to the view that, in a regulated environment, the community faces a choice between incurring the allocative efficiency costs of over-compensation and (more serious) dynamic costs of under-compensation. Both types of error are likely to influence investment outcomes and therefore have dynamic efficiency implications.

However, the PC(2001a) does seem to recognise that there is some form of efficiency trade-off, when it remarks (at page 4) that:

...it is important to encourage efficiency in the *use* of telecommunications infrastructure while also recognising that *incentives for investment* in telecommunications infrastructure need to be maintained. Investment in core infrastructure can be frustrated by unduly low access prices and excessive regulatory scope, while demand for services and investment in facilities dependent on the core infrastructure can be frustrated by unduly high access prices...

The Commerce Commission in New Zealand has explicitly recognised the potential for the type of static allocative and dynamic efficiency trade-off alluded to by NECG. The Commerce Commission (2001) outlines (at page 15, paragraph 70) that:

Where there are tensions between short-term allocative and long-term dynamic efficiency, the Commission takes the preliminary view that the latter will generally better promote the long term benefit of end users.

Guthrie, Small and Wright (GSW, 2001) and Evans and Guthrie (2002), investigate the impact backward-looking and forward-looking cost regulation have on the investment timing of a firm. Although neither paper explicitly refers to a static allocative efficiency and dynamic efficiency trade-off, both capture this type of trade-off. For example GSW outline (at page 3) that:

High access charges lead to a flow of surplus that is low but starts sooner, while low access charges lead to a flow of surplus that is high but starts later.

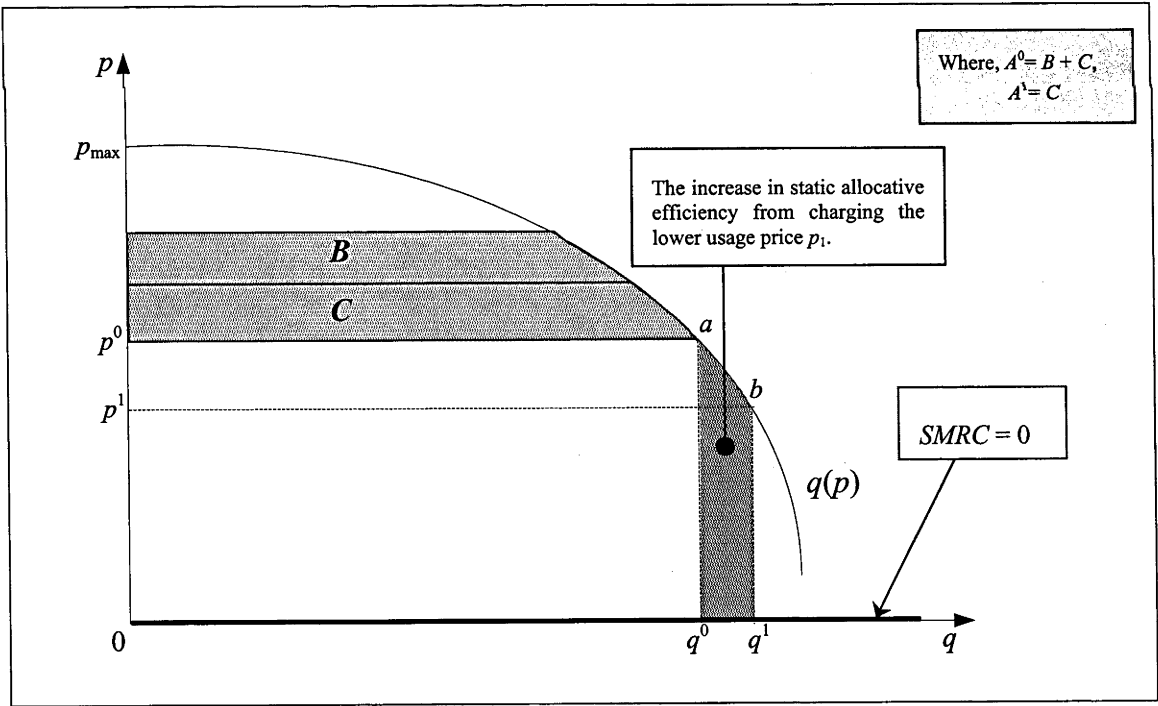
EQZ (2003) do explicitly refer to a static and dynamic efficiency trade-off. They outline that the potential for this type of trade-off is well established in the literature, citing the arguments made by Schumpeter (1942) that were outlined in Chapter 4. They capture the trade-off by investigating the optimal price monopolistic innovators should charge for the intermediate goods that are being provided for final production. EQZ find that this price, which they refer to as a "second-best price", is higher than the monopoly price, yet lower than the allocatively-efficient-short-run marginal cost.

### 6.4.3 Changing the Fixed Fee for Access

Although it has been established in Section 6.3 that in some circumstances the dynamically-efficient fixed access fee for the competitive investor can be less than zero, it is assumed for the remainder of the analysis in this Chapter that the fixed access fee is set so that  $CS(p) \geq A \geq 0$ . As is the standard case for a two-part tariff, any adjustment to the access charge here via a change in the fixed fee, will have no impact upon static allocative efficiency. The result arises because the fixed fee represents a lump-sum transfer from the consumer to the access provider, which by definition, does not distort the quantity of access demanded by consumers at the given usage price  $p$ .

Assuming the access provider initially bases its access charge on the usage price-fixed fee combination  $(p^0, A^0)$ , where  $CS(p^0) > A^0 > 0$ , the non-distortionary nature of changes in the fixed fee can be illustrated in Figure 6.4.2. This diagram indicates that if the access provider only decreases the access charge via a decrease in the fixed fee from  $A^0$  — shaded areas  $B + C$  — to  $A^1$  — shaded area  $C$  — the consumption of access remains unchanged at quantity  $q^0$ .

**FIGURE 6.4.2 DECREASES IN THE ACCESS CHARGE AND ALLOCATIVE EFFICIENCY**



A decrease in the access charge via a change in the fixed fee also means that there is no effect on the dynamically-efficient time  $t_w$ . However, as a change in the fixed fee changes the level of operating profit anticipated by the firm in any period after the

investment has occurred, it does have an impact upon the timing decision by the competitive and monopoly investor.

For both the competitive and monopoly investor, a decrease in the fixed fee  $A$ , decreases the revenue flow that the access provider can earn in any given period once the investment has been undertaken. Therefore, it provides the incentive to invest at a later time, when the costs of the investment have decreased sufficiently for the required rate of return to be earned. This outcome is confirmed by taking the derivative of the expressions for investment timing by a monopoly and competitive investor with respect to the fixed fee  $A$ . Using equations (6.2.11) and (6.2.16), it is found that,

$$\frac{dt_o}{dA} = \frac{dt_x}{dA} = -\frac{1}{\theta(\pi(p) + A)} < 0, \text{ where } CS(p) \geq A > 0 \quad (6.4.1)$$

As it is assumed the access charge is set so that  $A \leq CS(p)$ , it follows from Section 6.3 that the monopoly investor either invests at the dynamically-efficient time or inefficiently delays the investment. Consequently, a decrease in the fixed fee will always decrease dynamic efficiency.

For the competitive investor, a decrease in the fixed fee may either lead to an increase or decrease in dynamic efficiency. From Section 6.3, if  $\frac{rCS(p) - \theta\pi(p)}{\theta + r} \geq A$ , then the competitive investor either invests at the dynamically-efficient time or inefficiently delays the investment. A decrease in the fixed fee subsequently decreases the level of dynamic efficiency. If however, the access charge is set so that it initially satisfies the condition  $CS(p) \geq A > \frac{rCS(p) - \theta\pi(p)}{\theta + r}$ , then the competitive investor would have undertaken the investment too early, and a decrease in the fixed fee can potentially increase dynamic efficiency. An example where a decrease in the fixed fee results in the competitive investor increasing dynamic efficiency is provided in Figure 6.4.3.

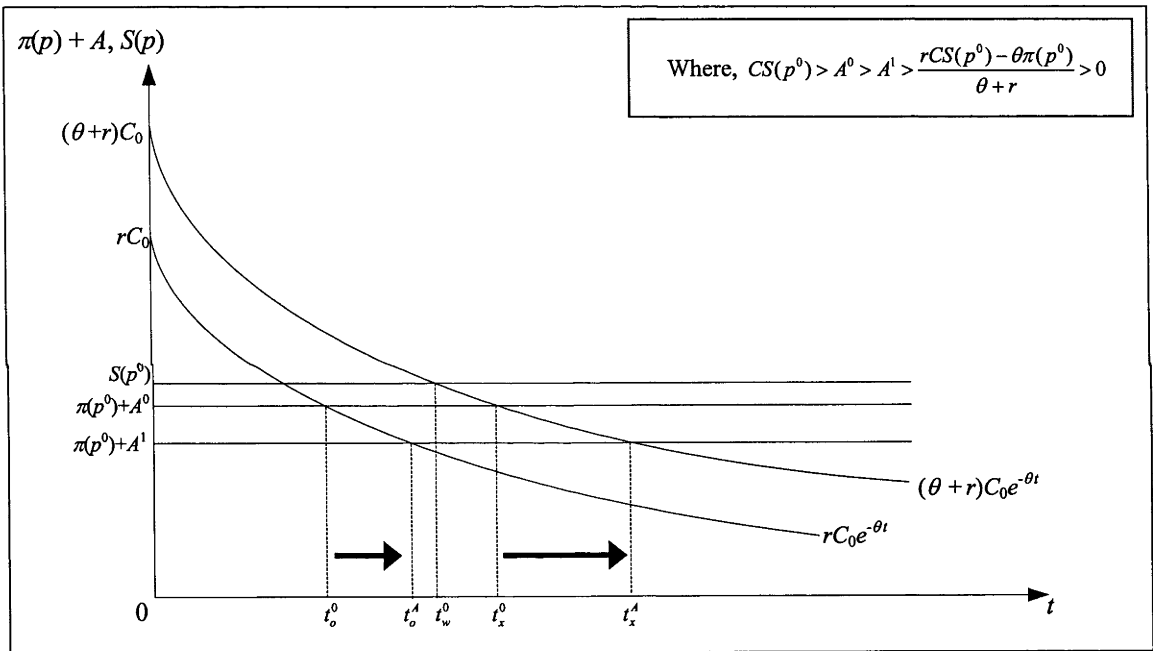
In Figure 6.4.3 it is assumed that the access provider initially sets the access charge based on the usage price-fixed fee combination  $(p^0, A^0)$ , where  $CS(p^0) > A^0 > \frac{rCS(p^0) - \theta\pi(p^0)}{\theta + r} > 0$ . The diagram shows that at the usage price  $p^0$ ,

dynamic efficiency is achieved by investing at time  $t_w^0$ . At the initial access charge though, it is apparent that the monopoly is inefficiently delaying the investment (i.e.  $t_x^0 > t_w^0$ ), while the firm facing competition to provide the essential facility, invests too



early (i.e.  $t_o^0 < t_w^0$ ). Decreasing the fixed fee to  $A^1$ , where  $A^0 > A^1 > \frac{rCS(p^0) - \theta\pi(p^0)}{\theta + r} > 0$ , decreases the level of dynamic efficiency achieved by the monopoly investor. Using superscript  $A$  to denote the investment timing under the lower fixed fee, the monopoly now invests at the later time  $t_x^A$ , where  $t_x^A > t_x^0 > t_w^0$ . For the competitive investor though, this decrease in the fixed fee leads to an increase in dynamic efficiency, as the investment occurs at the later time  $t_o^A$ , where  $t_w^0 > t_o^A > t_o^0$ . In these circumstances the dynamically-efficient outcome would have been achieved if the fixed fee were initially decreased by the amount  $A^0 - \frac{rCS(p^0) - \theta\pi(p^0)}{\theta + r}$ .

**FIGURE 6.4.3 THE EFFECT OF CHANGING THE FIXED ACCESS CHARGE**



#### 6.4.4 Changing the Usage Price for Access

A decrease in the access charge through a decrease in the usage price  $p$ , will affect the level of allocative efficiency, as the quantity of access demanded by the consumer rises. Assuming the usage price falls from  $p^0$  to  $p^1$  — because the short-run marginal cost of providing access by assumption is zero — the increase in short-run allocative efficiency is captured by the increase in social surplus, which in Figure 6.4.2 is depicted by area  $abq^1q^0$ . From Section 6.3, the decrease in the usage price  $p$  also leads to the dynamically-efficient time occurring earlier, and the new dynamically-efficient time generating a higher net present value to society.

Where  $p_m > p > 0$ ,<sup>18</sup> a decrease in the usage price  $p$ , leads to a fall in the revenue flows earned in each period by a monopoly and competitive investor. This induces both firms to provide the essential infrastructure at a later time, as the benefit relative to the cost of investing decreases. The outcome is confirmed by using the investment-timing expressions in equations (6.2.11) and (6.2.16), and taking the derivative of  $t_x$  and  $t_o$  with respect to  $p$ . This yields,

$$\frac{dt_x}{dp} = \frac{dt_o}{dp} = -\frac{1}{\theta} \frac{\pi'(p)}{\pi(p)} < 0, \text{ where } p_m > p > 0 \quad (6.4.2)$$

#### 6.4.4.1 Decreasing the Usage Price for a Monopoly Investor

For a **monopoly investor**, where  $p_m > p > 0$ , a **decrease in the usage price  $p$**  increases allocative efficiency and the level of social surplus, as the value to the consumer on the additional units of access supplied when the investment is undertaken exceeds the short-run cost to society of supplying those units. It does however lead to a decrease in dynamic efficiency, as the dynamically-efficient time to undertake the investment is earlier, yet the firm chooses to delay the investment further. This defers the realisation of the higher social surplus derived from using the infrastructure, but decreases the cost of undertaking the investment. The static allocative and dynamic efficiency trade-off here is characterised by a trade-off between:

- **the additional benefit** from the lower cost of undertaking the investment and the higher social surplus generated once the infrastructure is provided; and
- **the additional cost** of foregoing the flow of social surplus until a later time.

Therefore, a decrease in the usage price for access charged by a monopoly investor generates a higher (lower) net present value to society, when this additional benefit outlined above is greater (less) than the additional cost.<sup>19</sup> The issue is examined in more detail in Chapter 7, which looks at linear access pricing. In particular, it assesses whether linear price regulation of the monopoly investor is beneficial, and if it is, how the optimal linear price should be set.

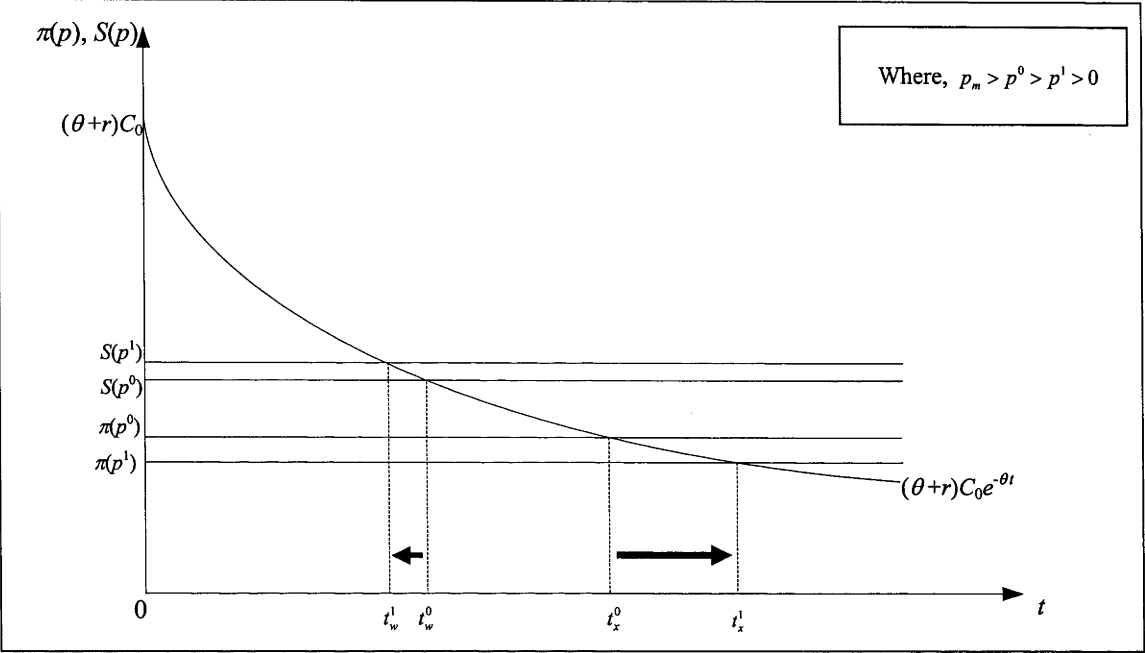
Assuming there is a usage price of  $p^0$ , where  $p_m > p^0 > 0$ , and no fixed fee (i.e.  $A = 0$ ), the impact a decrease in the usage price to  $p^1$  has on the dynamically-efficient time  $t_w$ ,

<sup>18</sup> Only considering prices where revenues are increasing in prices and concave, is consistent with the analysis of GSW (2001).

<sup>19</sup> This is the type of trade-off GSW (2001) outline will occur, when there is a downward drift in costs, and a lower access price.

and the investment timing of a monopoly investor  $t_x$ , is illustrated in Figure 6.4.4. The investment timing associated with the respective usage prices is denoted here using the superscript 0 and 1.

**FIGURE 6.4.4 THE USAGE PRICE AND DYNAMIC EFFICIENCY FOR A MONOPOLY**



### 6.4.4.2 Decreasing the Usage Price for a Competitive Investor

For the **competitive investor**, as was the case with a decrease in the fixed fee  $A$ , a **decrease in the usage price  $p$** , where  $p_m > p > 0$ , may either result in an increase or decrease in dynamic efficiency.

A decrease in dynamic efficiency, and subsequently a static allocative and dynamic efficiency trade-off arises, if prior to the price decrease occurring, the competitive firm would have invested at the dynamically-efficient time or inefficiently delayed the investment. From equation (6.3.10) and (6.3.14), this outcome requires that the initial usage price-fixed fee combination  $(p, A)$  satisfy the condition  $\frac{CS(p) - A}{\pi(p) + A} \geq \frac{\theta}{r}$ . As was

the case for the monopoly investor, a decrease in the usage price increases (decreases) the net present value to society if the additional benefit from the later investment is greater (less) than the additional cost.

An increase in both allocative and dynamic efficiency may arise if prior to the decrease in price occurring, the competitive firm would have invested too early. Rearranging the expression in equation (6.3.15), this outcome requires that the initial usage price-fixed

fee combination  $(p, A)$  satisfy the condition  $\frac{CS(p) - A}{\pi(p) + A} < \frac{\theta}{r}$ . Figure 6.4.5 provides an illustration of where such a condition is met. In the diagram, a decrease in the usage price from  $p^0$  to  $p^1$  leads to the competitive investor deferring the provision of the essential infrastructure, yet increasing the level of dynamic efficiency. For simplicity it is assumed in the diagram that there is no fixed fee (i.e.  $A = 0$ ).

**FIGURE 6.4.5 THE USAGE PRICE AND DYNAMIC EFFICIENCY UNDER COMPETITION**

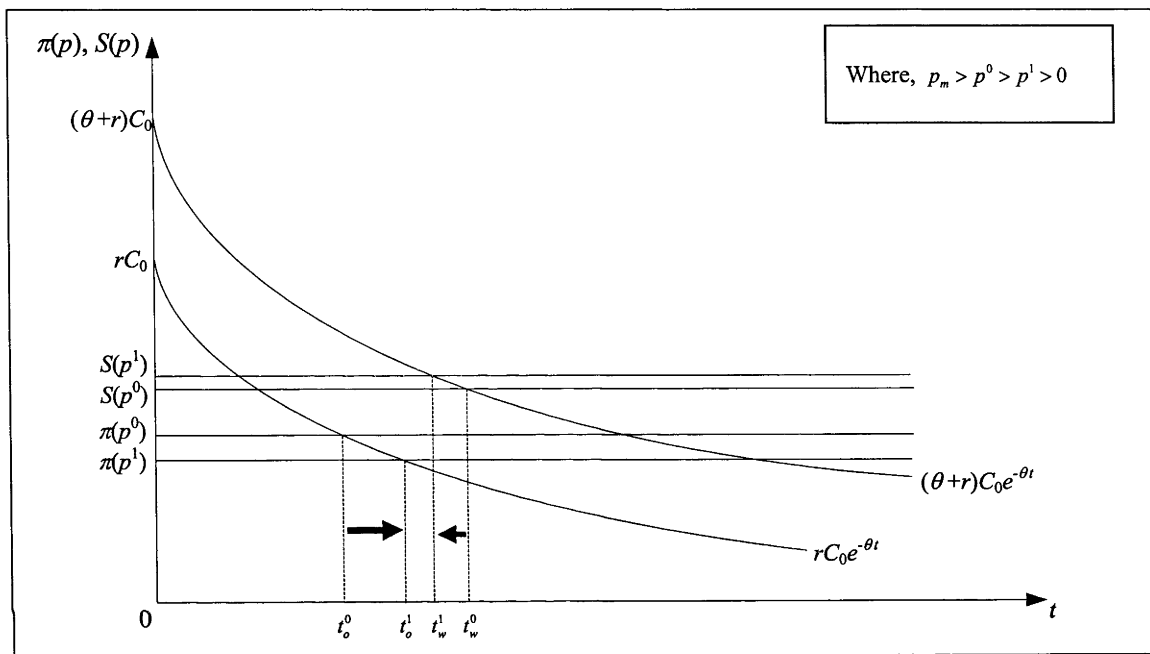


Figure 6.4.5 illustrates that the decrease in the usage price leads to the investment timing by the competitive investor being deferred from time  $t_o^0$  to  $t_o^1$ , while the socially-optimal time decreases from  $t_w^0$  to  $t_w^1$ . Although there is an increase in dynamic efficiency, there still exists some level of dynamic inefficiency, which implies that at  $p^1$ ,  $\frac{CS(p^1)}{\pi(p^1)} < \frac{\theta}{r}$ . As shown in equation (6.3.11), to induce the dynamically-efficient outcome in the absence of a fixed fee, the usage price for access must be reduced until,

$$\frac{CS(p)}{\pi(p)} = \frac{\theta}{r} \quad (6.4.3)$$

It is important to recognise that even though it is possible for a decrease in the usage price to increase both static allocative and dynamic efficiency, the same trade-off will still exist between:

- **the additional benefit** from the lower cost of the investment and the higher social surplus generated once the infrastructure is provided; and
- **the additional cost** of foregoing the flow of social surplus until a later time.<sup>20</sup>

A decrease in the usage price charged by the competitive investor once more only increases the net present value to society where this additional benefit is greater than the additional cost. The issue of the usage price that maximises the net present value to society achieved by the competitive investor, and its relationship with the usage price associated with the dynamically-efficient time in equation (6.4.3), is addressed in Chapter 7, Section 7.4.

#### 6.4.5 Assessing the Efficiency Trade-Off Claim

The analysis of this model demonstrates that a simple decrease in the access charge will not necessarily generate the trade-off claimed to arise between static allocative and dynamic efficiency. It is shown here that while a decrease in the fixed fee  $A$  effects the level of dynamic efficiency, an efficiency trade-off will only occur if the access charge is decreased through a decrease in the usage price  $p$ .<sup>21</sup> Therefore, it appears that those analysts claiming there is a static allocative and dynamic efficiency trade-off resulting from some change in the access charge, must either be dealing with industries where the regulator is considering whether to adjust the usage price for access, or industries where there is only a linear price for access.

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<sup>20</sup> GSW, Evans and Guthrie, and EQZ, all outline a similar type of trade-off occurring in their models, which examine the impact access pricing has on investment timing.

<sup>21</sup> Gans and Williams (1999a) and the majority of the work done by Gans (2001), examines the impact a change in the fixed fee for access has upon investment timing and welfare. In Section 6, Gans does consider the optimal usage price, although he does not seem to refer to any dynamic and static allocative efficiency trade-off.

## 6.5 Rate-of-Return (ROR) Regulation of a Monopoly Investor

In this Section it is assumed the regulator can control the rate of return that the firm is allowed to earn on the backward-looking (BL) or original cost of its investment. That is, for any given linear access price  $p$  and fixed fee  $A$ , the regulator sets an allowed fair rate of return  $f$  on the original cost of the investment, which is less than the unregulated rate of return  $\theta + r$  a monopoly investor is able to earn. By doing this, the regulator induces the monopoly investor to undertake the investment at an earlier time. Where the regulator restricts the allowed rate of return to the normal rate of return  $r$ , the results are equivalent to the outcomes derived for the competitive investor in Section 6.2. In addition, it is illustrated that in relation to investment timing, an equivalence result once again exists between ROR regulation of the monopoly investor and a capital subsidy. These results are shown to have potential policy implications for the regulation of investors.

### 6.5.1 Investment Timing under ROR Regulation on BL Costs

For any given linear price  $p$  and fixed fee  $A$ , the constraint imposed by using ROR regulation and only allowing the firm to earn the fair rate  $f$  on the original or BL cost of the investment, is captured in the following equation.

$$\frac{\pi(p) + A}{C_0 e^{-\theta t_{xr}}} = f < \theta + r \quad (6.5.1)$$

In equation (6.5.1),  $t_{xr}$  represents the investment timing by the ROR-regulated monopoly investor for any given linear price  $p$  and fixed fee  $A$ . It is equal to,

$$t_{xr} = \frac{1}{\theta} \log \left( \frac{f C_0}{\pi(p) + A} \right) < t_{xm} = \frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{\pi(p) + A} \right), \text{ where } f < \theta + r \quad (6.5.2)$$

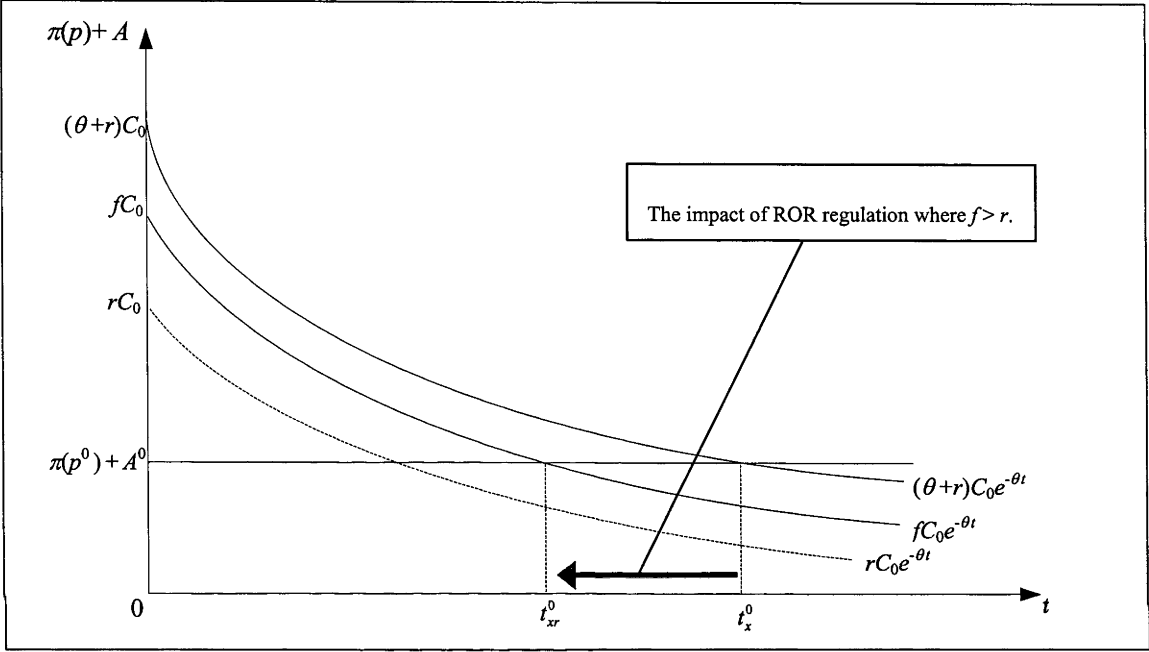
This outcome reflects that ROR regulation induces earlier investment timing by the monopolist, as it restricts the rents the investor can achieve. If the assumption is also made that the fair rate  $f$  is higher than the normal rate of return  $r$ , then the net present value that is derived by the ROR-regulated monopoly investor from investing at the earlier time  $t_{xr}$ , will be equal to,

$$NPV_f^{xr}(p, A) = \frac{1}{r} \left( \frac{(f - r)(\pi(p) + A)}{f} \right) \left( \frac{\pi(p) + A}{f C_0} \right)^{\frac{r}{\theta}}, \text{ where } \theta + r > f > r \quad (6.5.3)$$

The derivation of the expression in equation (6.5.3) is outlined in the Appendix to this Chapter in Section A.6.4.

The earlier investment timing by the monopoly investor under ROR regulation can be illustrated in Figure 6.5.1. In this diagram it is assumed that the firm charges some access fee consisting of a usage price  $p^0$  and fixed fee  $A^0$ , and the resulting investment times are denoted by superscript 0.

**FIGURE 6.5.1 THE IMPACT OF ROR REGULATION ON THE MONOPOLY INVESTOR**



As outlined in Chapter 2, Section 2.5.7, the regulator is often under a statutory duty to establish a framework that simulates the effects of a competitive market. If reproducing the competitive market effect is interpreted by the regulator as requiring that the firm earns a fair rate equal to normal rate of return (i.e.  $f = r$ ), ROR regulation of the monopoly investor has the same effect as having a perfect competition to undertake investment. For example, at any given linear price  $p$  and fixed fee  $A$ , the ROR-regulated monopoly invests at time,

$$t_{xr}(p, A) = t_o(p, A) = \frac{1}{\theta} \log \left( \frac{rC_0}{\pi(p) + A} \right) \quad (6.5.4)$$

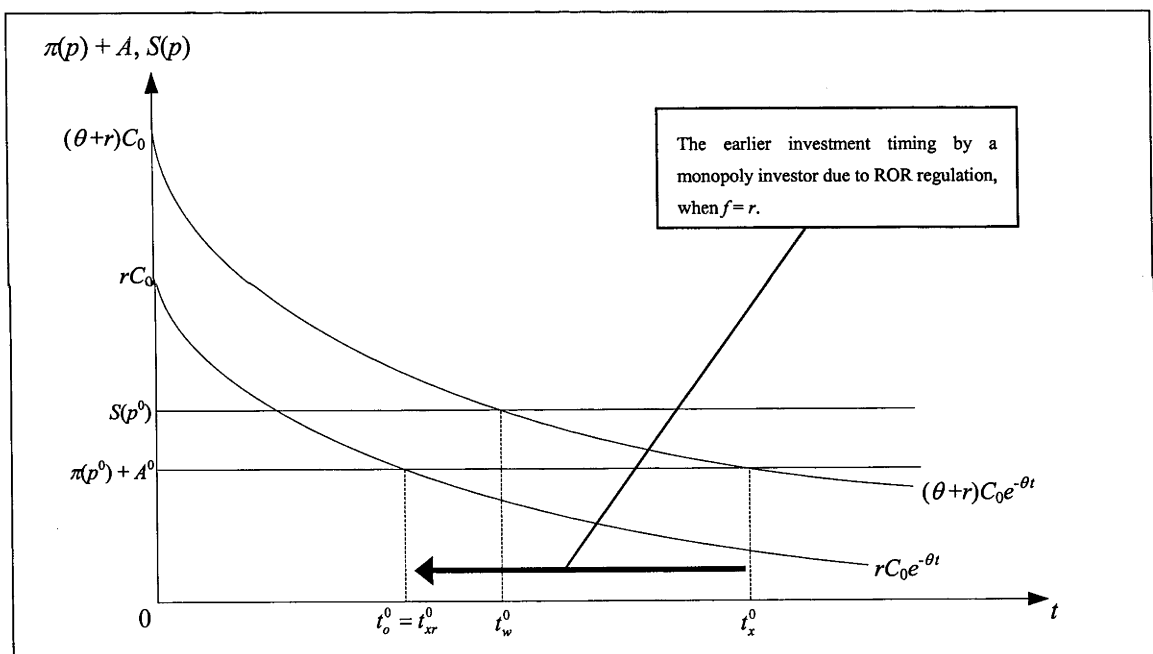
and the firm derives a net present of zero from undertaking the investment. As the results for the ROR-regulated monopoly investor are identical to those achieved by a competitive investor, throughout the remainder of Chapters 6 and 7, the outcomes under ROR regulation are denoted using the notation adopted for the competitive investor.

Like the competitive investor, the monopoly investor subject to ROR regulation, may either invest prior to, at, or after the dynamically-efficient time  $t_w(p)$ . From the analysis in Section 6.3.3, for the given access charge  $(p, A)$ , ROR-regulation leads to the monopoly investor:

- continuing to inefficiently delay the investment if  $\frac{rCS(p) - \theta\pi(p)}{\theta + r} > A$ ;
- investing at the dynamically-efficient time if  $A = \frac{rCS(p) - \theta\pi(p)}{\theta + r}$ ; and
- providing the essential infrastructure too early if  $CS(p) \geq A > \frac{rCS(p) - \theta\pi(p)}{\theta + r}$ .

An example of where ROR regulation induces the monopoly investor to provide the essential infrastructure too early is illustrated in Figure 6.5.2.

**FIGURE 6.5.2 INVESTMENT TIMING OF THE ROR-REGULATED MONOPOLY INVESTOR**



In this diagram it is once more assumed that the access charge consists of the given usage price-fixed fee combination  $(p^0, A^0)$ . The monopoly investor not subject to any fair rate and facing this access charge invests at time  $t_x^0$ . The ROR-regulated monopoly investor facing the fair rate  $f = r$ , provides the essential infrastructure at the earlier time  $t_o^0$ , but invests prior to the dynamically-efficient time associated with usage price  $p^0$ ,  $t_w^0$ .

This implies that the access charge is such that,  $CS(p^0) > A^0 > \frac{rCS(p^0) - \theta\pi(p^0)}{\theta + r}$ .



### 6.5.2 The Higher Investment Cost under ROR Regulation

The earlier provision of the essential infrastructure by a monopoly investor subject to ROR regulation means that, compared to the unregulated outcome, there is a higher cost to the firm and society of undertaking the investment. Further, this cost is higher the closer the fair rate  $f$  is set to the normal rate of return on capital  $r$ . This result appears consistent with findings in static models, which suggest that the ROR-regulated monopoly has an incentive to incur a higher cost of production to society. However, unlike these models, the increased cost of production here does not actually reflect any cost inefficiency from an input distortion, capital waste or padding of costs. The higher cost from undertaking the investment earlier arises in this framework, because of the cost-decreasing rate of technological progress  $\theta$ .

### 6.5.3 The Benefit to Society of ROR Regulation

If the monopoly investor is restricted to earning the same normal rate of return  $r$  as the competitive investor, then from equation (6.2.17), the net present value derived by society will be,

$$NPV_s^o(p, A) = \frac{1}{r} (CS(p) - A) \left( \frac{\pi(p) + A}{rC_0} \right)^{\frac{r}{\theta}} \quad (6.5.5)$$

As ROR regulation of the monopoly investor may either increase or decrease dynamic efficiency, it can also increase or decrease the net present value derived by society. ROR regulation will unambiguously increase dynamic efficiency and the net present value to society, if it leads to the monopoly investor being dynamically efficient or still engaging in inefficient delay. This occurs if at any given access charge  $(p, A)$ ,  $\frac{rCS(p) - \theta\pi(p)}{\theta + r} \geq A$ . ROR regulation of the monopoly investor may only decrease

dynamic efficiency and the net present value to society, if it induces the monopoly investor to provide the essential infrastructure before the socially-optimal time  $t_w(p)$ . Such an outcome is possible if at any given usage price  $p$  and fixed fee  $A$ ,  $CS(p) > A > \frac{rCS(p) - \theta\pi(p)}{\theta + r}$ .<sup>22</sup>

<sup>22</sup> If at the given access charge  $CS(p) = A$ , then the monopoly investor would have originally invested at the dynamically-efficient time, and the introduction of ROR regulation will unambiguously decrease dynamic efficiency and the benefit to society.

#### 6.5.4 Equivalence of ROR Regulation and the Capital Subsidy

Chapter 2 and 3 establish an equivalence result between the capital subsidy and ROR regulation in the Averch and Johnson (1962) model. In relation to the monopoly investor, it appears that a similar equivalence result exists in this framework with respect to investment timing. ROR regulation and the capital subsidy both induce earlier investment, and a lower fair rate has the same effect upon investment timing as providing the monopoly investor with a higher capital subsidy at time 0.

It is assumed that at time 0, the monopoly investor is provided with a capital subsidy  $s$ , such that the original cost of the investment is  $C_z$ , where  $C_z = (1 - s)C_0$ . With this subsidy provided on each unit of the original cost of the investment  $C_0$ , for a given linear access price  $p$  and fixed fee  $A$ , the firm achieves the required rate of return  $\theta + r$  at the earlier time of  $t_z(p, A)$ .

$$t_z(p, A) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_z}{\pi(p) + A} \right) < t_x(p, A) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{\pi(p) + A} \right) \quad (6.5.6)$$

Therefore, although the capital-subsidised investor achieves a higher rate of return than the ROR-regulated monopoly investor, both schemes induce earlier investment timing. Equating the timing of the ROR-regulated monopoly investor subject to some fair rate  $f$  — where  $\theta + r > f \geq r$  — with the timing of the capital-subsidised monopoly investor, it is possible to derive an expression for the equivalent capital subsidy  $s$  at any given fair rate  $f$ . That is, equating the expression for  $t_z(p, A)$  in equation (6.5.6), with the expression for  $t_{xr}(p, A)$  in equation (6.5.2), and solving yields,

$$s(f) = \left( 1 - \frac{f}{\theta + r} \right), \text{ where } (\theta + r) > f \geq r \quad (6.5.7)$$

Taking the first derivative of equation (6.5.7), confirms that, for a monopoly investor as the fair rate of return  $f$  converges towards the normal rate of return  $r$ , it has the same effect on timing as providing the firm with a higher capital subsidy  $s$ .

$$\frac{ds}{df} = \frac{-1}{\theta + r} < 0 \quad (6.5.8)$$

From equation (6.5.8), in terms of timing, the capital subsidy that is equivalent to restricting the monopoly investor to earning the normal rate of return on capital  $r$  is,

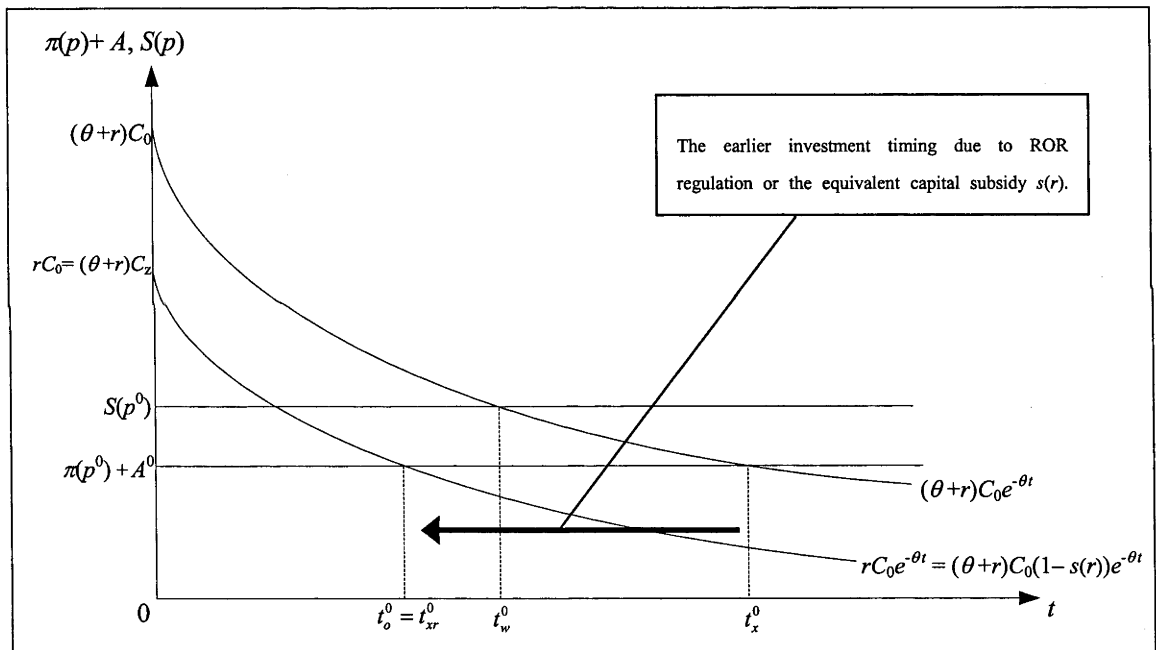
$$s(r) = \left( \frac{\theta}{\theta + r} \right) \quad (6.5.9)$$

Therefore, as was the case with ROR-regulated monopoly subject to the normal rate of return, the earlier investment timing due to the capital subsidy can either lead to the monopoly investor:

- continuing to inefficiently delay the investment;
- undertaking the investment at the dynamically-efficient time  $t_w(p_m)$ ; or
- providing the essential infrastructure too early.

Similarly, the capital subsidy may only decrease the net present value to society if it induces the investment to occur prior to the dynamically-efficient time. An outcome where the capital subsidy  $s(r)$  leads to the monopoly investor providing the essential infrastructure inefficiently early is illustrated in Figure 6.5.3. In the diagram it is once again assumed that there is a given access charge  $(p^0, A^0)$ .

**FIGURE 6.5.3 THE EQUIVALENCE OF ROR REGULATION AND A CAPITAL SUBSIDY**



From Section 6.4.1, it appears that providing the monopoly investor with a higher capital subsidy has the same impact upon timing as providing the monopoly investor, allowed to charge a two-part tariff, with a higher fixed fee.<sup>23</sup> Hence, from the equivalence between ROR regulation and the capital subsidy, it also follows that in

<sup>23</sup> Gans (2001) makes the point that the socially-optimal outcome can be achieved using a fixed access charge, despite the absence of a government subsidy.

terms of investment timing, ROR regulation of the monopoly investor is equivalent to increasing the fixed fee  $A$ .

Although ROR regulation has the same impact upon timing as providing the monopoly investor with either a capital subsidy or a higher fixed fee, the same equivalence does not apply for the competitive investor. While a capital subsidy and an increase in the allowed fixed fee induce earlier investment timing by a competitive investor, ROR regulation has no impact. The reason for this is that ROR regulation merely simulates the effects of having a perfectly-competitive market to provide the essential infrastructure, something that a competitive investor by definition, is already subject to.

#### 6.5.5 Policy Implications of the Equivalence Results from ROR Regulation

The analysis here shows that, with investment costs in an industry decreasing over time due to technological progress, ROR regulation of the monopoly investor can be used to simulate the effects of a competitive market to undertake the investment. For a given access charge, by restricting the rate of return the monopoly investor is allowed to earn, the regulator induces the firm to invest earlier. This can potentially decrease the dynamic inefficiency that arises from having a monopoly investor. As earlier investment is achieved without allowing the investor any economic rent, it may be considered more publicly acceptable than inducing the same earlier investment timing by means of a capital subsidy or a higher fixed fee.

The equivalence the outcomes for the ROR-regulated monopoly investor and the competitive investor also highlights the obvious point that, where there is a competitive market to undertake the investment, the regulator need not bother applying ROR regulation. If there were some cost associated with using regulatory instruments, the application of ROR regulation would just represent a waste of society's resources.

Finally, the equivalence established between ROR regulation of the monopoly investor and the unregulated competitive investor suggests that, in an industry subject to rapid cost-decreasing technological progress over time, ROR regulation will not provide the necessary market discipline after the essential infrastructure has been built. ROR regulation here, only simulates the effect of competition for the market, and does not simulate the effect of competition in the market. Therefore, if the regulator wants to discipline a competitive or monopoly investor's pricing behaviour after the infrastructure has been built, it needs to consider using an additional regulatory instrument on the firm. The PC (2001b) appears to recognise a similar problem when it

highlights the potential for monopoly pricing to occur after an investment has been undertaken. It states (at page 71) that:

Competition at the construction phase will sometimes occur against a back-drop of the potential for the successful investor to charge monopoly prices once it has become established as the incumbent provider.

The addition of price regulation to simulate the effects of competition within the market is considered in greater detail in Chapter 7.

## 6.6 The Socially-Optimal Investment

This Section highlights the usage price and investment timing that maximises the net present value to society. As in Gans (2001), it is found here that it is possible for an investor to achieve the welfare-maximising outcome if it can charge a two-part access tariff. The monopoly investor can achieve the welfare-maximising outcome if it is left unregulated and allowed to charge a two-part tariff that maximises its profit. In contrast, a competitive or ROR-regulated monopoly investor charging the same two-part access tariff undertakes the investment too early. To maximise the net present value to society, the competitive or ROR-regulated monopoly investor must charge the same allocatively efficient usage charge as the unregulated monopoly investor, but a lower fixed fee, the level of which is decreasing in the rate of technological progress. This result suggests that an access holiday may not be necessary to induce the efficient investment outcome, and a lower access charge may be appropriate in industries experiencing a higher rate of technological progress. The final sub-section outlines industries where two-part tariffs are used, and briefly considers why such access prices have not been adopted in telecommunications.

### 6.6.1 The Socially-Optimal Outcome

As the socially-optimal time at any given usage price  $p$  has already been found in Section 6.3, in order to find an outcome that maximises the net present value to society, the benevolent social planner must choose the optimal per-unit access price  $p$ . This is done by,

$$\max_p NPV_s^w(p) = \frac{1}{r} \left( \frac{\theta S(p)}{\theta + r} \right) \left( \frac{S(p)}{(\theta + r) C_0} \right)^{\frac{r}{\theta}} \quad (6.6.1)$$

which yields the FOC,

$$\frac{dNPV_s^w}{dp} = \frac{1}{r} \left( \frac{S(p)}{(\theta + r) C_0} \right)^{\frac{r}{\theta}} S'(p) = 0 \quad (6.6.2)$$

Solving equation (6.6.2), the optimal usage price set by the benevolent social planner is  $p^* = 0$ . As the social surplus will be equal to its maximum possible value (i.e.  $S(0) = S_{\max}$ ), the dynamically-efficient time in equation (6.3.3),  $t_w$  will now be,

$$t_w(p^* = 0) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{S_{\max}} \right) \quad (6.6.3)$$

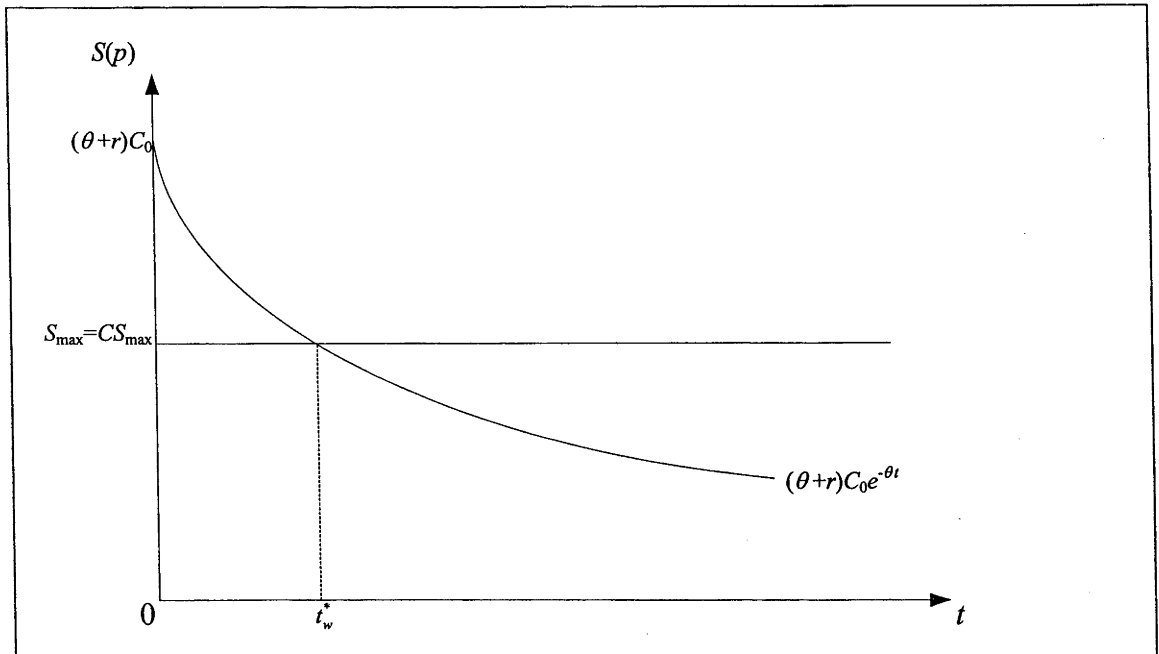
The intuition for why price  $p^* = 0$ , and the corresponding investment timing  $t_w(p^* = 0)$ , maximises the overall net present value to society, is that it is both allocatively and dynamically efficient. Allocative efficiency is achieved because the usage price here is being set equal to the zero short-run marginal cost of production. This price maximises the total benefits to society that can be achieved at each instant in time after the investment in the essential infrastructure has been provided.

Substituting  $p^* = 0$  into the expression for the maximum net present value for society, yields,

$$NPV_s^w(p^* = 0) = \frac{1}{r} \left( \frac{\theta S_{\max}}{\theta + r} \right) \left( \frac{S_{\max}}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (6.6.4)$$

The socially-optimal outcome described here is depicted in Figure 6.6.1. For convenience in this diagram, the socially-optimal timing for the investment  $t_w(p^* = 0)$  is denoted by  $t_w^*$ .

**FIGURE 6.6.1 THE SOCIALLY-OPTIMAL INVESTMENT**



#### 6.6.2 Achieving the Socially-Optimal Outcome with a Monopoly Investor

The analysis in Section 6.3.3 established that the dynamically-efficient investment time at any given usage price  $p$  —  $t_w(p)$  — will be achieved if the monopoly investor charges a two-part tariff, where the fixed fee is set equal to the consumer surplus derived at

usage price  $p$  (i.e.  $A = CS(p)$ ). Therefore, an identical outcome to the social planner is obtained if the monopoly investor is left unregulated and allowed to perfectly-price discriminate, or equivalently in this model, set a two-part access tariff that consists of an allocatively-efficient zero usage price  $p^* = 0$  and a fixed fee of  $A_x^* = CS(0) = S_{\max}$ .<sup>24</sup> Such a result has been recognised by the PC (2001b), which notes (at page 72, Box 4.2) that Gans (2001) has outlined that:

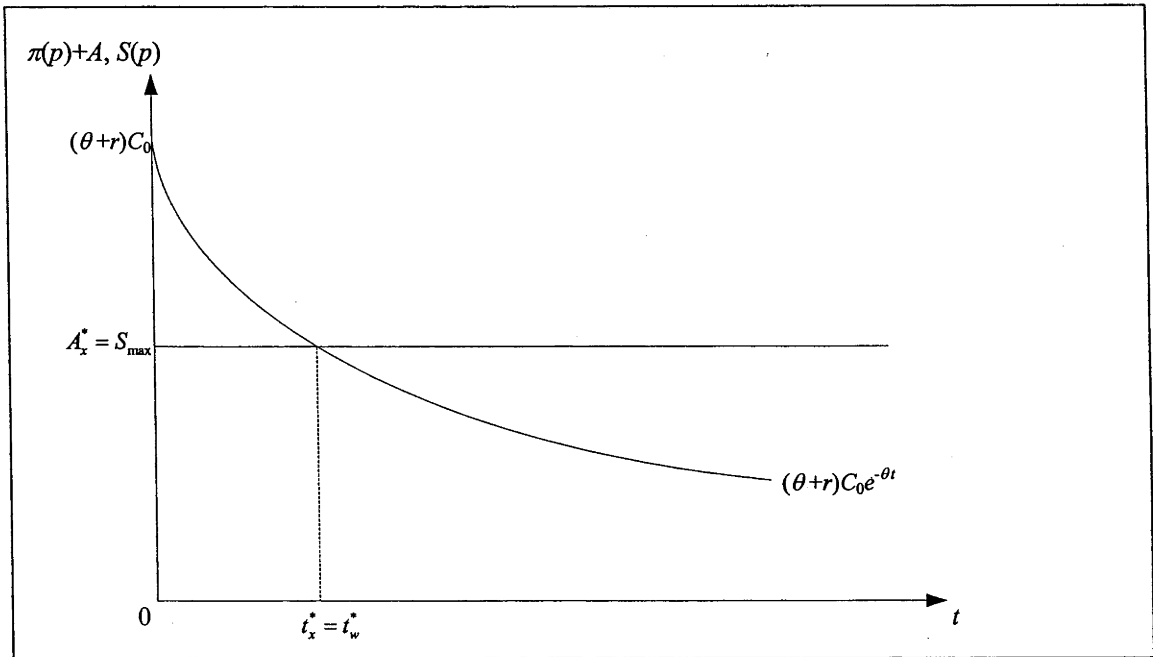
...if the incumbent provider had the capacity to set charges that discriminated perfectly between service users on the basis of their willingness to pay, it would (re)invest at the socially optimal time. This outcome is analogous to the outcome in the static model where perfect price discrimination eliminates the allocative efficiency costs of monopoly.

The timing of the monopoly investor allowed to charge the fixed fee  $A_x^* = S_{\max}$  is,

$$t_x(0, S_{\max}) = \frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{S_{\max}} \right) = t_w^* \tag{6.6.5}$$

The investment timing under such a two-part access tariff is depicted in Figure 6.6.2, where the investment timing of the monopoly  $t_x(p^* = 0, A_x^* = S_{\max})$  is denoted by  $t_x^*$ .

FIGURE 6.6.2 THE SOCIALLY-OPTIMAL OUTCOME WITH A MONOPOLY INVESTOR



<sup>24</sup> The result is similar to an outcome in the optimal patent literature highlighted by Tirole (1989) in Chapter 10, pages 390-1.



The two-part access tariff here maximises the net present value of the firm and achieves the socially-optimal outcome by internalising all the benefits to society derived from the investment. Subsequently, the expression for the maximum net present value to the firm is identical to the expression for the net present value to society in equation (6.6.4), and is equal to,

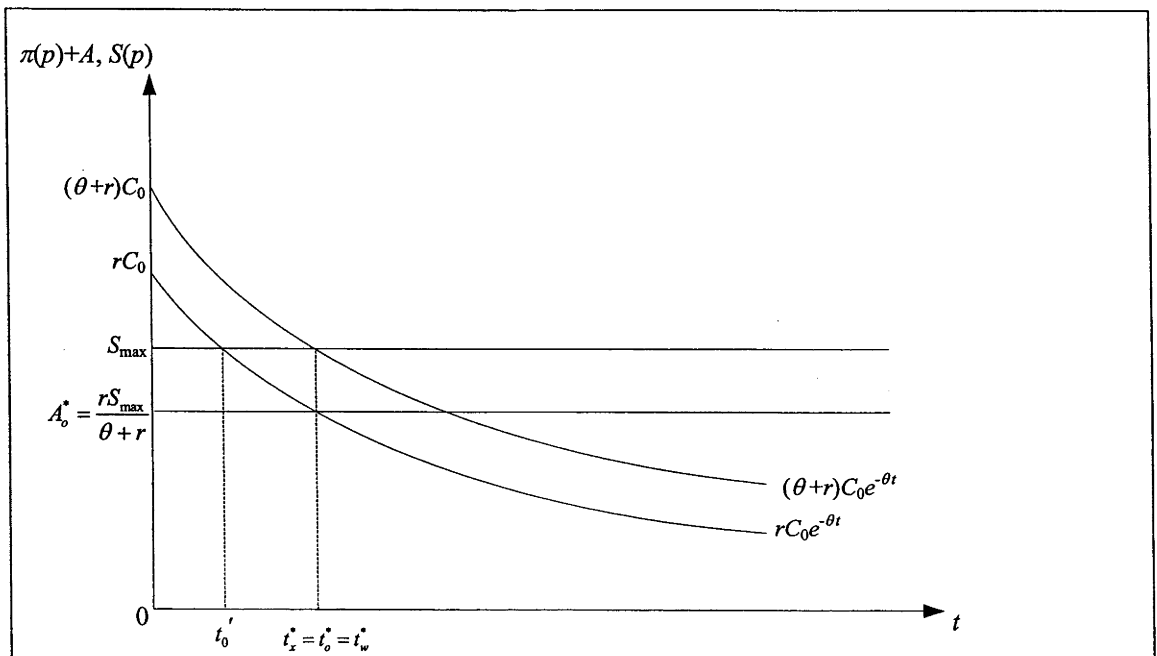
$$NPV_f^x(0, S_{\max}) = \frac{1}{r} \left( \frac{\theta S_{\max}}{\theta + r} \right) \left( \frac{S_{\max}}{(\theta + r) C_0} \right)^{\frac{r}{\theta}} = NPV_s^w(p^* = 0) \quad (6.6.6)$$

**6.6.3 The Social Optimum with a Competitive or ROR-Regulated Monopoly Investor**  
Where there is a competitive market for providing infrastructure, or ROR regulation of the monopoly investor, the two-part access tariff,  $p^* = 0$  and  $A = S_{\max}$ , induces premature investment in the essential facility. That is, the firm invests at time,

$$t_o(0, S_{\max}) = \frac{1}{\theta} \log \left( \frac{r C_0}{S_{\max}} \right) < t_w^* \quad (6.6.7)$$

The outcome from charging the dynamically-inefficient-two-part access tariff for the competitive or ROR-regulated monopoly investor,  $p^* = 0$  and  $A = S_{\max}$ , is depicted in Figure 6.6.3. The inefficient investment timing by such firms,  $t_o(p^* = 0, A = S_{\max})$ , is denoted in the diagram by  $t_0'$ .

**FIGURE 6.6.3 THE SOCIALLY-OPTIMAL OUTCOME WITH COMPETITION**



The timing of the investment described by equation (6.6.7) and illustrated in Figure 6.6.3, leads to the ROR-regulated monopoly or competitive investor generating a net present value to the firm and society of zero (i.e.  $NPV_f(0, S_{\max}) = NPV_s(0, S_{\max}) = 0$ ).

The reason for the dynamic inefficiency and failure to achieve the socially-optimal outcome with a competitive investor is that a problem arises similar to the “tragedy of the commons”. Unlike the unregulated monopoly investor who has an exclusive right to invest, in a competitive market, potential investors vie for the right to provide the essential infrastructure. At the access charge  $p^* = 0$  and  $A = S_{\max}$ , because the property right to invest is initially undefined and is obtained on a “first-come first-serve basis”, competition for the investment destroys social surplus. The PC (2001b) alludes to this type of problem when it recognises (at page 72) that, while the impact of the “competition to construct” reduces economic rents, it could lead to premature investment in capacity.

From analysis in Section 6.3, at the allocatively-efficient usage price  $p^* = 0$ , to induce the competitive or ROR-regulated monopoly investor to undertake the investment at the dynamically-efficient time, the fixed fee must be set so that  $A_o^* = rS_{\max}/\theta + r$ . Such an access charge yields,

$$t_o(p^* = 0, A_o^* = \frac{rS_{\max}}{\theta + r}) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{S_{\max}} \right) = t_w^* \quad (6.6.8)$$

The timing of the investment by a dynamically-efficient competitive or ROR-regulated monopoly investor — i.e.  $t_o(p^* = 0, A_o^* = rS_{\max}/\theta + r)$  — is denoted in Figure 6.6.3 by  $t_o^*$ .

The net present value to society derived by the competitive and ROR-regulated monopoly investor from charging this two-part access tariff,  $p^* = 0$  and  $A_o^* = rS_{\max}/\theta + r$ , is now identical to the net present value to society achieved by the social planner.

$$NPV_s^o(p^* = 0, A = \frac{rS_{\max}}{\theta + r}) = \frac{1}{r} \left( \frac{\theta S_{\max}}{\theta + r} \right) \left( \frac{S_{\max}}{(\theta + r)C_0} \right)^{\frac{1}{\theta}} = NPV_s^w(p^* = 0) \quad (6.6.9)$$

Unlike the socially-optimal fixed fee for the unregulated monopoly investor  $A_x^*$ , the socially-optimal fixed fee  $A_o^*$  does not extract the entire surplus from the consumer, and its level depends upon the rate of technological progress. By taking the derivative of  $A_o^*$  with respect to the rate of technological progress  $\theta$ , it is shown that the higher the

rate of technological progress is, the lower the optimal fixed fee that should be charged by the competitive or ROR-regulated monopoly investor.<sup>25</sup> That is,

$$\frac{dA_o^*}{d\theta} = -\frac{rS_{\max}}{(\theta + r)^2} < 0 \quad (6.6.10)$$

In terms of public policy, the results suggest that in order to achieve the socially-optimal outcome, it may not be necessary to provide the monopoly investor with a period of no regulation — i.e. an access holiday. Instead of leaving the monopoly investor unregulated, the socially-optimal investment outcome can be achieved by restricting the fair rate of return the monopoly investor is allowed to earn, and requiring the firm to charge a lower fixed fee for access.

#### 6.6.4 Two-Part Access Tariffs in Practice

Although two-part access tariffs can potentially induce the socially-optimal investment, it is prudent to recognise that they are not always used in particular industries.

Biggar (2001) outlines that two-part tariffs are used to price access in the natural gas transmission and distribution sector, and in the rail-track sector. In these sectors, the fixed charge is typically set quite high, and only a small element of total costs depends upon the volume of gas, or the number of trains transported over the network. In the telecommunications industry, Biggar notes that while two-part access tariffs are employed to price services in the retail sector, they are rarely used to price access to the network.<sup>26</sup> Citing a report by the OECD from 2001, he highlights that, at the time, no member country adopted two-part tariffs for pricing interconnection, and access charges were typically based on a simple linear per-minute charge. Biggar does however suggest that there is scope for moving towards greater use of two-part tariff in telecommunications.

The ACCC has consistently queried the feasibility of adopting a two-part access charge in telecommunications access pricing in Australia. For example, ACCC (2000b)

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<sup>25</sup> While the PC (2001a) appears to recognise there is less need for prolonged periods of high access charges in industries experiencing rapid technological progress (at page 289), it appears more concerned with the potentially adverse impact that an “access holiday” (i.e. no regulation) may have on additional investment and competition in downstream markets.

<sup>26</sup> Biggar does mention that two-part access tariffs were proposed by Mercury for the UK in 1995, and led to undesirable outcomes when briefly used to price access to the unbundled network elements in Finland.

remarks (at Attachment 3, page 6) that “it is difficult to conceive of multi-part pricing being used for access”, while ACCC (2001) states that “the calculation of an efficient two-part access price is extremely difficult both in principle and in practice.” The ACCC appears particularly concerned with the potential for a multi-part access tariff to deter entry into the downstream markets. ACCC (2001) notes (at page 22) that because a two-part access tariff imposes a fixed cost upon the access seeker, it can create a natural monopoly effect in the downstream markets, and decrease competition.<sup>27</sup> The PC (2001a) however, believes that the dismissal of multi-part tariffs by the ACCC is premature, and considers there is some scope for such pricing arrangements. It proposes the pricing principle (at page 384) that:

*Access prices should allow multi-part tariffs and price discrimination when it aids efficiency.*

Woodbridge (2001) suggests that multi-part tariffs are not more readily observed in pricing access because of the prohibitive cost associated with gathering information about the access seeker’s marginal valuations. This is evident from his statement (at page 14) that:

Multi-part pricing rules are not common in access pricing however, mainly because of the informational requirements necessary for the regulator to set efficient up-front fees.

and his conclusion (at page 15) that:

Although this approach has merit, in practice it may be difficult to ascertain the value that each party is likely to derive from the use of the asset.

However, this explanation appears slightly unsatisfactory given that two-part tariffs are used to price access in some network industries, and to price services in telecommunication retail markets.

The prevalence of two-part access tariffs in markets such as gas and rail track, and linear access prices in telecommunications, may be explained by the different market structures that have emerged post-deregulation in these industries. The deregulation of rail, electricity and gas, has generally led to the vertically-integrated incumbent being structurally separated. For example, in gas and electricity, the assets of the incumbent

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<sup>27</sup> Biggar (2001) also outlines (at page 15) that a multi-part access tariff may turn a competitive downstream market into a natural monopoly activity. He claims that such an outcome occurred in the telecommunications market in Finland.

were separated, sold-off and placed into generation, transmission, distribution and retail markets. In contrast, across many countries, the deregulation of telecommunications has generally involved introducing competition in the wholesale and retail market, but preserving the vertically-integrated incumbent in some shape or form.

Under the different market structures, if a two-part tariff for access were set too high in the structurally-separated gas, electricity or rail track markets, the access providers would earn no income. The access provider therefore has an incentive to decrease the tariff eventually until some positive quantity of access is demanded. In contrast, if the vertically-integrated telecommunications incumbent were to set a two-part access tariff that was too high, it would still earn positive profit, as it preserves its status as a monopoly, and just eliminates any competition in the downstream retail market. The ability of the vertically-integrated monopoly to use two-part access tariffs in such a way as to eliminate or threaten the level of downstream competition may go some way towards explaining why regulators have been reluctant to allow two-part tariffs in pricing access in telecommunications.

As there is a linear access price used in telecommunications, and in this framework only an adjustment in the linear price brings about the type of static and dynamic efficiency trade-off that has been claimed arises in these industries; the following Chapter ignores the fixed fee  $A$ , and focuses upon the regulation of the linear access price  $p$  for a monopoly and competitive investor. Although the model outlined here does not capture the behaviour of a vertically-integrated monopoly, it can still be used to highlight a number of relevant issues that a regulator might want take into account when setting a linear access prices in industries experiencing rapid technological progress.

## 6.7 Conclusion

This Chapter examined the investment timing and social surplus for a monopoly and competitive investor, charging a two-part access tariff, in an industry experiencing a constant rate of cost-decreasing technological progress. While the model adopted in here involved many simplifying assumptions, (e.g. guaranteeing the regulated firm recovers the cost of the investment), it was established that many of the results could be used to assess and capture various issues and ideas raised in the PC (2001a) and PC (2001b) reports.

Throughout the course of the Chapter it was shown that:

- a competitive investor always invests earlier than a monopoly investor;
- the dynamically-efficient or socially-optimal time is dependent on the level of usage price;
- at a given access charge, the monopoly investor may only induce a better outcome for society than the competitive investor, in instances where the competitive investor provides the essential infrastructure before the socially-optimal time;
- a change in the access charge via a change in the fixed fee only affects dynamic efficiency;
- the static allocative and dynamic efficiency trade-off only arises if the change in the access charge is brought about by a change in the usage price for access;
- although there may be an increase in both static allocative and dynamic efficiency for the competitive investor, a lower usage price still always generates a trade-off between the:
  - **additional benefit** to society from the higher social surplus and lower investment cost when the investment occurs; and
  - **additional cost** to society from deferring the investment and delaying the flow of social surplus until a later time.
- under ROR regulation of the monopoly investor, when the fair rate  $f$  is set equal to  $r$ , it is equivalent to having perfect competition to undertake the investment. Subsequently, the outcomes for the ROR-regulated monopoly investor are identical to those achieved by a competitive investor;
- ROR regulation of the monopoly investor and the capital subsidy have an equivalent impact upon investment timing;

- ROR regulation does not affect the behaviour of the competitive investor and the same capital subsidy equivalence derived for the monopoly investor does not hold;
- as in Gans (2001), the socially-optimal outcome arises if the investor can charge a two-part access tariff;
- the unregulated monopoly induces the social optimum if it is allowed to charge the two-part access tariff that maximise its profits. However, a competitive or ROR-regulated monopoly investor using the same access charge invests too early;
- for the competitive or ROR-regulated monopoly investor to achieve the social optimum, a fixed fee must be charged that is:
  - less than that required by the unregulated monopoly investor; and
  - lower, the higher the rate of technological progress is.

The results suggest that access holidays may not be required to induce the optimal investment.

As Section 6.6 indicates that two-part access tariffs are not always used to regulate certain industries (e.g. telecommunications), the next Chapter employs the model outlined here to assess and compare the optimal linear price for access with a monopoly and competitive investor.

## A.6 Chapter 6 Appendix

### A.6.1 The Net Present Values to the Firm and Society with a Monopoly Investor

By substituting the expression for the investment timing in equation (6.2.11) into equation (6.2.6), the **net present value derived by the firm** when it is a monopoly investor is,

$$\begin{aligned}
 NPV_f^x(p, A) &= \frac{1}{r}(\pi(p) + A)e^{-\frac{r}{\theta} \log\left[\frac{(\theta+r)C_0}{\pi(p)+A}\right]} - C_0 e^{-\frac{(\theta+r)}{\theta} \log\left[\frac{(\theta+r)C_0}{\pi(p)+A}\right]} \\
 &= \left(\frac{\pi(p) + A}{r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}} - C_0 \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{\theta+r}{\theta}} \\
 &= \left(\frac{\pi(p) + A}{r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}} - \left(\frac{\pi(p) + A}{\theta+r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}} \\
 &= \left(\frac{\pi(p) + A}{r} - \frac{\pi(p) + A}{\theta+r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}} \\
 &= \frac{1}{r} \left(\frac{(\pi(p) + A)(\theta+r) - r(\pi(p) + A)}{\theta+r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}} \\
 &\Rightarrow NPV_f^x(p, A) = \frac{1}{r} \left(\frac{\theta(\pi(p) + A)}{\theta+r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}}
 \end{aligned}$$

This is the outcome for the net present value to the firm given by equation (6.2.12).

By substituting the expression for the investment timing in equation (6.2.11) into equation (6.2.7), the **net present value derived by society** under a monopoly investor is,

$$\begin{aligned}
 NPV_s^x(p, A) &= \frac{1}{r}S(p)e^{-\frac{r}{\theta} \log\left[\frac{(\theta+r)C_0}{\pi(p)+A}\right]} - C_0 e^{-\frac{(\theta+r)}{\theta} \log\left[\frac{(\theta+r)C_0}{\pi(p)+A}\right]} \\
 &= \left(\frac{S(p)}{r} - \frac{\pi(p) + A}{\theta+r}\right) \left(\frac{\pi(p) + A}{(\theta+r)C_0}\right)^{\frac{r}{\theta}}
 \end{aligned}$$

As  $S(p) = \pi(p) + CS(p)$ , it follows that,



$$NPV_s^x(p, A) = \frac{1}{r} \left( \frac{\theta \pi(p) + (\theta + r) CS(p) - rA}{\theta + r} \right) \left( \frac{\pi(p) + A}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}$$

$$\Rightarrow NPV_s^x(p, A) = \frac{1}{r} \left( \frac{\theta S(p) + r(CS(p) - A)}{\theta + r} \right) \left( \frac{\pi(p) + A}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}$$

This is the outcome for the net present value to society given by equation (6.2.13).

#### A.6.2 The Net Present Values Society with a Competitive Investor

By substituting the expression for the investment timing in equation (6.2.15) into equation (6.2.7), the **net present value derived by society** when there is a competitive market for the investment is,

$$NPV_s^o(p, A) = \frac{1}{r} S(p) e^{-\frac{r}{\theta} \log[\frac{rC_0}{\pi(p)+A}]} - C_0 e^{-\frac{(\theta+r)}{\theta} \log[\frac{rC_0}{\pi(p)+A}]}$$

$$= \left( \frac{S(p)}{r} - \frac{\pi(p) + A}{r} \right) \left( \frac{\pi(p) + A}{rC_0} \right)^{\frac{r}{\theta}}$$

As  $S(p) = \pi(p) + CS(p)$ , it follows that,

$$NPV_s^o(p, A) = \frac{1}{r} (\pi(p) + CS(p) - \pi(p) - A) \left( \frac{\pi(p) + A}{rC_0} \right)^{\frac{r}{\theta}}$$

$$\Rightarrow NPV_s^o(p, A) = \frac{1}{r} (CS(p) - A) \left( \frac{\pi(p) + A}{rC_0} \right)^{\frac{r}{\theta}}$$

This is the outcome for the net present value to society given by equation (6.2.17).

#### A.6.3 The Maximum Net Present Value to Society

By substituting the expression for the dynamically-efficient time in equation (6.3.3) into equation (6.2.7), the **maximum net present value derived by society** at any given usage charge for access  $p$  is,

$$NPV_s^w(p) = \frac{1}{r} S(p) e^{-\frac{r}{\theta} \log[\frac{(\theta+r)C_0}{S(p)}]} - C_0 e^{-\frac{(\theta+r)}{\theta} \log[\frac{(\theta+r)C_0}{S(p)}]}$$

$$= \left( \frac{S(p)}{r} - \frac{S(p)}{\theta + r} \right) \left( \frac{S(p)}{(\theta + r) C_0} \right)^{\frac{r}{\theta}}$$

$$= \left( \frac{\theta S(p)}{r(\theta + r)} \right) \left( \frac{S(p)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}}$$

$$\Rightarrow NPV_s^w(p) = \frac{1}{r} \left( \frac{\theta S(p)}{\theta + r} \right) \left( \frac{S(p)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}}$$

This is the outcome for the net present value to society given by equation (6.3.4).

**A.6.4 The Net Present Value to the Firm with a ROR-Regulated Monopoly Investor**  
 Substituting the expression for investment timing by the ROR-regulated monopoly investor in equation (6.5.2) into equation (6.2.6), and assuming that the fair rate is such that  $\theta + r > f > r$ , then at any given access charge  $(p, A)$ , the **net present value derived by the ROR-regulated monopoly investor** will be,

$$NPV_f^{xr}(p, A) = \frac{1}{r} (\pi(p) + A) e^{-\frac{r}{\theta} \log[\frac{fC_0}{\pi(p)+A}]} - C_0 e^{-\frac{(\theta+r)}{\theta} \log[\frac{fC_0}{\pi(p)+A}]}$$

$$= \left( \frac{\pi(p) + A}{r} - \frac{\pi(p) + A}{f} \right) \left( \frac{\pi(p) + A}{fC_0} \right)^{\frac{r}{\theta}}$$

$$= \left( \frac{\pi(p) + A}{r} - \frac{\pi(p) + A}{f} \right) \left( \frac{\pi(p) + A}{fC_0} \right)^{\frac{r}{\theta}}$$

$$= \frac{1}{r} \left( \frac{(f - r)(\pi(p) + A)}{f} \right) \left( \frac{\pi(p) + A}{fC_0} \right)^{\frac{r}{\theta}}$$

$$\Rightarrow NPV_f^{xr}(p, A) = \frac{1}{r} \left( \frac{(f - r)(\pi(p) + A)}{f} \right) \left( \frac{\pi(p) + A}{fC_0} \right)^{\frac{r}{\theta}}$$

This is the expression for the net present value outlined in equation (6.5.3).

# CHAPTER 7: LINEAR ACCESS PRICING, INVESTMENT TIMING AND EFFICIENCY

## 7.1 Introduction

This Chapter uses the model established in Chapter 6 to analyse the impact that linear price regulation of the investor has on investment timing, dynamic efficiency and the net present value to society.

### 7.1.1 The Problem with a Short-Run-Marginal-Cost-Based Price

As shown in Section 6.4 and 6.6, the allocatively-efficient outcome in the framework adopted here, requires the usage price to be set equal to the short-run marginal cost of production. With no fixed fee, the problem with such a linear price is that, while it covers the ongoing period-to-period expenses, (which for simplicity were assumed to be equal to zero in the model); it fails to provide the firm with an adequate level of compensation to ever undertake the investment in the first place.

This type of problem is highlighted in an ACCC (2001) submission to the Productivity Commission inquiry report on *Telecommunications Competition Regulation*, when it states (at page 22) that, while “SRMC [short-run marginal cost] may appear to be ‘efficient’ in the short run as it appears to equate the marginal value of the use to the value given up in supplying that unit...this make no allowance for what is given up in ‘keeping the productive capacity alive’”. The PC (2001a) outlines (at page 383) that it “agrees with the ACCC” in relation to the shortcomings of short-run-marginal-cost pricing and this “is precisely why the [Productivity] Commission does **not** endorse SRMC as a pricing methodology”.

### 7.1.2 Existing Literature on Linear Price Regulation

There has been extensive literature examining the issue of efficient cost recovery using linear prices, in circumstances where marginal-cost pricing (short-run or long-run) fails

to recover cost of the investment.<sup>1</sup> Much of the work in this area, examining the required mark-up of price above marginal cost, has been done in a static framework, and is based on the analysis of Ramsey (1927) and Boiteux (1956).<sup>2</sup>

Ramsey (1927) looked at the most efficient method of raising a given amount of tax revenue across a number markets using distortionary taxes. He found that with no cross-price effects, the most efficient way to raise revenues across markets was by setting a tax that distorted price away from marginal cost, in accordance with the inverse elasticity of demand for the good. That is, the lower (higher) the elasticity of demand is, the greater (lower) the proportionate mark-up that is required in price from the marginal cost in that market. Boiteux (1956) independently derived an identical outcome to Ramsey, but formulated the problem in the terms of public utility retail pricing and the natural monopoly problem.<sup>3</sup> He examined the optimal linear retail price that should be charged when marginal cost-based pricing fails to recover costs.<sup>4</sup>

For some market  $i$ , where  $\varepsilon_{di}$  denotes the price elasticity of demand and  $\lambda$  the Ramsey number, the linear pricing rule established by Ramsey and Boiteux — Ramsey-Boiteux pricing — can formally be written,

$$\frac{p_i - MC_i}{p_i} = \frac{\lambda}{\varepsilon_{di}}, \text{ where } 0 < \lambda < 1, \varepsilon_{di} > 0 \quad (7.1.1)^5$$

As the socially-optimal method for recovering costs for the sustainable natural monopoly involves a two-part tariff — where price is set equal to marginal cost and the remaining costs covered using a fixed fee — this optimal linear Ramsey-Boiteux price in equation (7.1.1), has often been classified as second-best efficient.

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<sup>1</sup> In the short-run, pricing at marginal cost fails to recover the fixed cost associated with the investment. In the long run setting price equal to the marginal cost does not recover all costs, if there are joint or common costs associated with the network.

<sup>2</sup> Berg and Tschirhart (1988) provide a good summary of efficient regulatory linear pricing in Chapter 3.

<sup>3</sup> The original article is in French, and a translated version is found in Boiteux (1971). Rees (1968) derives a similar solution to Boiteux, by examining the natural monopoly problem in a general-equilibrium framework.

<sup>4</sup> Baumol and Bradford (1970) were the first to highlight the link between the articles by Ramsey and Boiteux.

<sup>5</sup> Dreze (1964) shows that if the assumption of no cross-price effects is relaxed, a similar rule applies with a super-elasticity formula for the Ramsey-Boiteux price.

The basic Ramsey-Boiteux pricing formula has been extended to incorporate more complex retail pricing problems. For example, Braeutigam (1979) examines the optimal linear price for a natural monopoly given there exists a competitive fringe, while Brock and Dechert (1985) looks at the optimal linear Ramsey-Boiteux price in an intertemporal setting. Further, Laffont and Tirole (1994) and Armstrong, Doyle and Vickers (1996), have also established that the optimal linear access price for a network with joint, common or unattributable costs, should be based on Ramsey-Boiteux principles.

The optimal linear price and its impact on investment timing, dynamic efficiency and the net present value to society, has only been dealt with very recently. As mentioned in the previous Chapter, Guthrie, Small and Wright (GSW, 2001), Evans and Guthrie (2002) and Evans, Quigley and Zhang (EQZ, 2003) all appear to examine the impact that a linear price has on investment timing.<sup>6</sup> As the analysis of GSW and Evans and Guthrie use a real options approach, they rely on numerical outcomes and do not derive an analytical solution for the optimal linear price. EQZ though, do derive an optimal linear price for the intermediate goods used to produce the final output in the economy. This price is found to be higher than the allocatively-efficient-short-run marginal cost, but lower than the unregulated monopoly price.

### 7.1.3 Results and Contributions of this Chapter

This Chapter uses the framework from Chapter 6 to examine the impact that a linear access price has on the net present value to society, given that the allocatively-efficient-short-run-marginal-cost-based price in this model, fails to provide the firm with adequate compensation for the cost of its investment. The analysis here looks at the monopoly and competitive (or ROR-regulated monopoly) investors' behaviour when they are allowed to charge an unregulated price, and then examines the impact of price regulation on the firm. From this, an optimal linear price is derived for the monopoly and competitive investor, and is found to have similar properties to the second-best price derived by EQZ. A linear demand curve and numerical example is used to compare the outcomes under the respective regimes. The issue of forward-looking cost

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<sup>6</sup> Gans (2001) also considers the issue of the optimal usage price for access in Section 6. However, while his analysis examines the impact a linear access price has on the strategic incentive to pre-empt the investment, it still uses a two-part tariff for access, as it looks at the implications this has for the level of the socially-optimal fixed fee.

regulation is also briefly dealt with, and this appears to reinforce the outcomes from Chapter 5. As in Chapter 6, throughout the course of this Chapter, the issues raised about access pricing and investment in the Productivity Commission reports — PC (2001a,b) — are incorporated into the analysis. This allows any potential policy implications of the results established here to be highlighted.

The Chapter is structured as follows. Section 7.2 examines the outcome where the monopoly and competitive investor are allowed to charge an unregulated linear price. Section 7.3 examines the investment timing of a monopoly investor under price regulation, and establishes the condition that the optimal linear price must satisfy. This analysis is repeated in Section 7.4 for a competitive or ROR-regulated monopoly investor. Using a linear demand curve a numerical example is provided in Section 7.5, which compares price, investment timing, and the net present value to society, under each of the different access regimes that have been considered. The same linear demand curve and parameters are used in Section 7.6 to assess FL cost regulation. Section 7.7 concludes the analysis in the Chapter.

## 7.2 The Investor Charging an Unregulated Linear Price

This Section examines the outcome when an investor is allowed to charge an unregulated linear price for access once the essential infrastructure has been provided. It is found that the monopoly and competitive (or ROR-regulated monopoly) investor generate the same level of allocative inefficiency — by pricing at the unregulated linear monopoly price  $p_m$  — but different levels of dynamic efficiency. While the monopoly investor is dynamically inefficient, as it invests later than the socially-optimal time  $t_w(p_m)$ , the competitive or ROR-regulated monopoly investor may either invest before, at, or after  $t_w(p_m)$ . The competitive or ROR-regulated monopoly investor may only be more dynamically inefficient, and yield a lower net present value to society than the monopoly investor, if the investment occurs prior to time  $t_w(p_m)$ .

### 7.2.1 The Monopoly Investor

A monopoly investor, charging an unregulated linear price for access, aims to maximise the expression for the net present value for the firm, given by equation (6.2.12). That is, where  $A = 0$ , the monopoly chooses  $p$  to,

$$\max_p NPV_f^x(p) = \frac{1}{r} \left( \frac{\theta \pi(p)}{\theta + r} \right) \left( \frac{\pi(p)}{(\theta + r) C_0} \right)^{\frac{\epsilon}{\theta}} \quad (7.2.1)$$

The first-order condition (FOC) is,

$$\frac{dNPV_f^x}{dp} = \frac{1}{r} \left( \frac{\pi(p)}{(\theta + r) C_0} \right)^{\frac{\epsilon}{\theta}} \pi'(p) = 0 \quad (7.2.2)$$

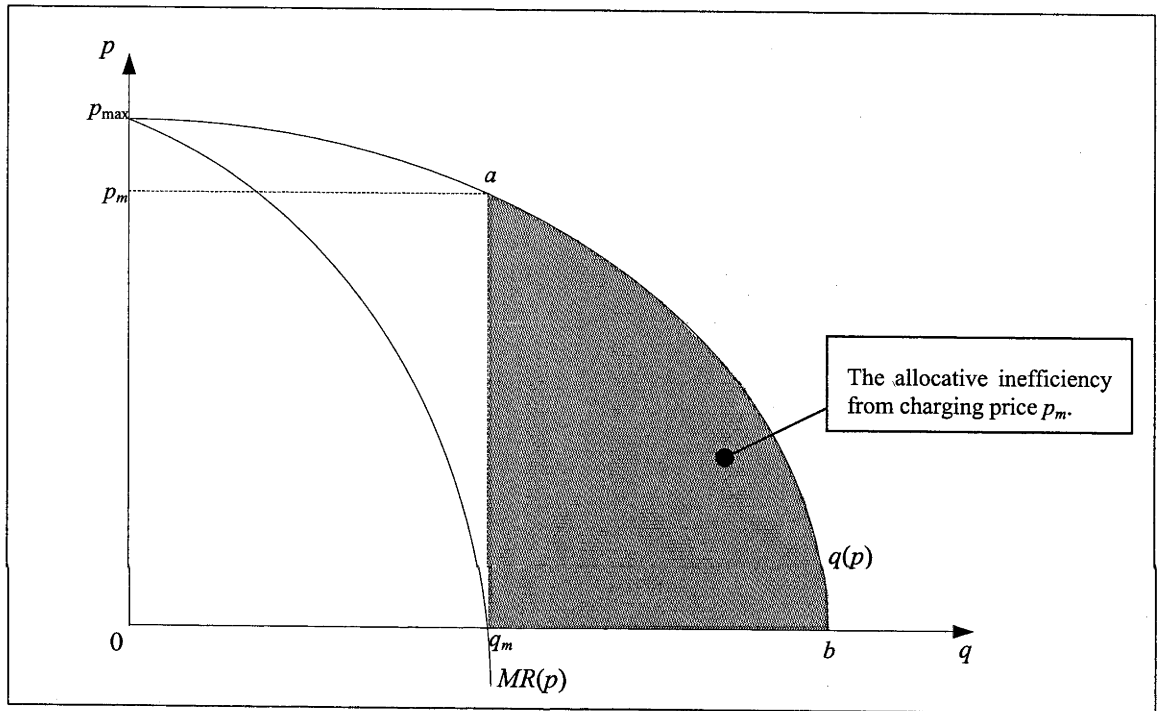
The outcome in equation (7.2.2) implies that, to maximise the payoff to the firm, an unregulated monopoly investor must charge a linear access price at each instant in time, where the marginal revenue ( $MR$ ) from supplying access —  $\pi'(p)$  — is equal to zero. As the short-run marginal cost ( $SRMC$ ) is also zero, the access price in each period is effectively being set at a level where, the marginal revenue from production is equal to the short-run marginal cost of supplying access (i.e.  $MR = SRMC$ ). The unregulated monopoly investor achieves this outcome by restricting the amount of access it supplies to  $q_m$ , and setting the linear access price  $p_m$ .

As the monopoly investor charges a per-unit price  $p_m$  that exceeds the  $SRMC$  of zero, at each instant in time after the essential infrastructure is provided there is some level of allocative inefficiency. This leads to a deadweight loss ( $DWL$ ) at each instant of,

$$DWL(p_m) = S(0) - S(p_m) \quad (7.2.3)$$

In Figure 7.2.1, the inefficiency at each instant in time is highlighted by the shaded area  $abq_m$ , while the total revenue at each instant  $\pi_m$ , is equal to area  $pmaq_m0$ .

**FIGURE 7.2.1 ALLOCATIVE INEFFICIENCY FROM THE UNREGULATED PRICE**



Substituting price  $p_m$  into the equation for the investment timing by a monopoly investor given by Table 6.3.1 or equation (6.2.11), implies that

$$t_x(p_m) = \frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{\pi(p_m)} \right) \quad (7.2.4)$$

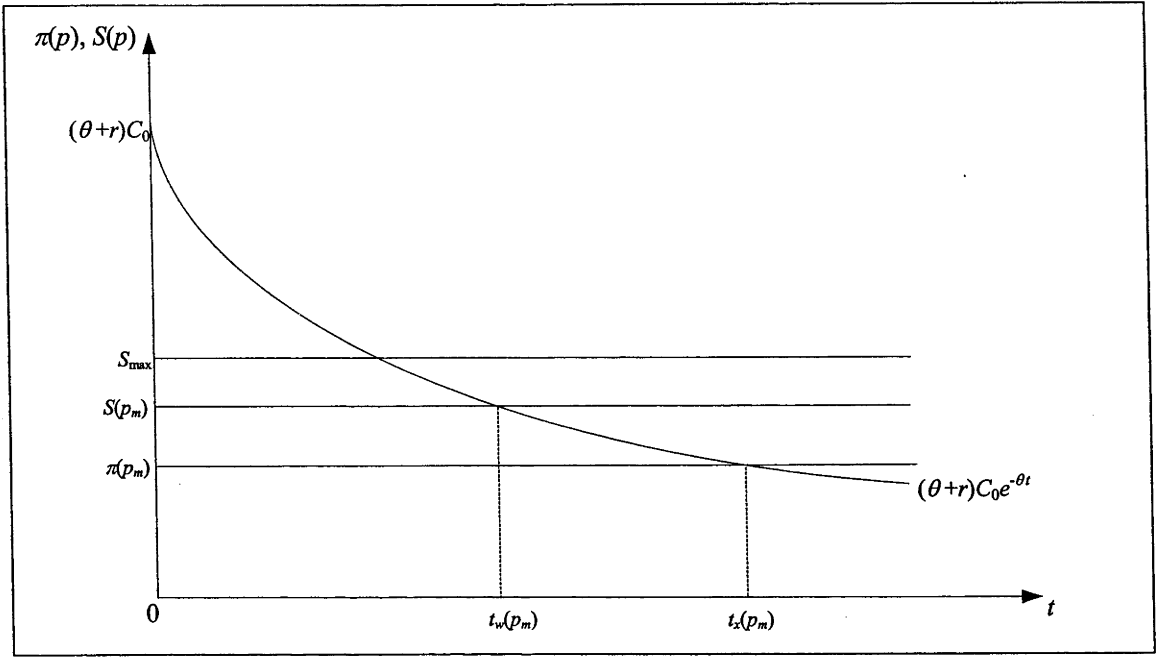
This is later than the dynamically-efficient time at price  $p_m$ , which is given by Table 6.3.1 or equation (6.3.3), and is equal to,

$$t_w(p_m) = \frac{1}{\theta} \log \left( \frac{(\theta + r) C_0}{S(p_m)} \right), \text{ where } S(p_m) = \pi(p_m) + CS(p_m) \quad (7.2.5)$$

The dynamic inefficiency from the firm inefficiently delaying the investment, so that the flows of social surplus are realised too late, is shown in Figure 7.2.2.



FIGURE 7.2.2 DYNAMIC INEFFICIENCY OF A MONOPOLY INVESTOR



From equation (6.2.12) or Table 6.3.1, the net present value to the monopoly investor charging the linear price  $p_m$  is,

$$NPV_f^x(p_m) = \frac{1}{r} \left( \frac{\theta \pi(p_m)}{\theta + r} \right) \left( \frac{\pi(p_m)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (7.2.6)$$

Further, equation (6.2.13) or Table 6.3.1 indicates that the net present value to society is,

$$NPV_s^x(p_m) = \frac{1}{r} \left( \frac{\theta S(p_m) + rCS(p_m)}{\theta + r} \right) \left( \frac{\pi(p_m)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (7.2.7)$$

The outcome in equation (7.2.7) is lower than the optimal outcome in equation (6.6.4).

### 7.2.2 The Competitive or ROR-Regulated Monopoly Investor

With a perfect competition to provide the essential infrastructure, or ROR regulation of the monopoly investor where the fair rate  $f$  set equal to  $r$ , regardless of the linear access price that is charged, the investor earns a net present value of zero. To avoid having a non-unique linear access price, it is initially assumed here that either: the investing firm subject to competition to construct has a slight cost advantage over the other potential investors; or that the fair rate  $f$  is being set slightly above the normal rate of return  $r$ . This implies the investor earns a slightly above normal rate of return  $r + \varepsilon$ , where  $\varepsilon > 0$ . Setting the fixed fee equal to zero (i.e.  $A = 0$ ) and substituting  $r + \varepsilon$  in for the term  $f$  in

equation (6.5.3), at any given linear price access  $p$ , the net present value derived by the firm will be,

$$NPV_f^o(p) = \frac{1}{r} \left( \frac{\varepsilon \pi(p)}{r + \varepsilon} \right) \left( \frac{\pi(p)}{(r + \varepsilon) C_0} \right)^{\frac{r}{\theta}} \quad (7.2.8)$$

To find the linear price that this investor charges to maximise its net present value, the derivative of equation (7.2.8) is taken with respect to  $p$ , and the resulting expression set equal to zero.

$$\frac{dNPV_f^o}{dp} = \frac{1}{r} \left( \frac{\varepsilon}{r + \varepsilon} \right) \left( \frac{\theta + r}{\theta} \right) \left( \frac{\pi(p)}{(r + \varepsilon) C_0} \right)^{\frac{r}{\theta}} \pi'(p) = 0 \quad (7.2.9)$$

The result implies that as with the unregulated monopoly investor, a ROR-regulated monopoly investor and competitive investor, earning the slightly above normal rate of return  $r + \varepsilon$ , will also charge the linear access price  $p_m$ .

From equation (6.2.16), the competitive investor or ROR-regulated monopoly investor earning the return  $r + \varepsilon$ , will invest at time

$$t_o(p_m) = \frac{1}{\theta} \log \left( \frac{(r + \varepsilon) C_0}{\pi(p_m)} \right)$$

Assuming  $\varepsilon \rightarrow 0$ , the above equation simplifies to,

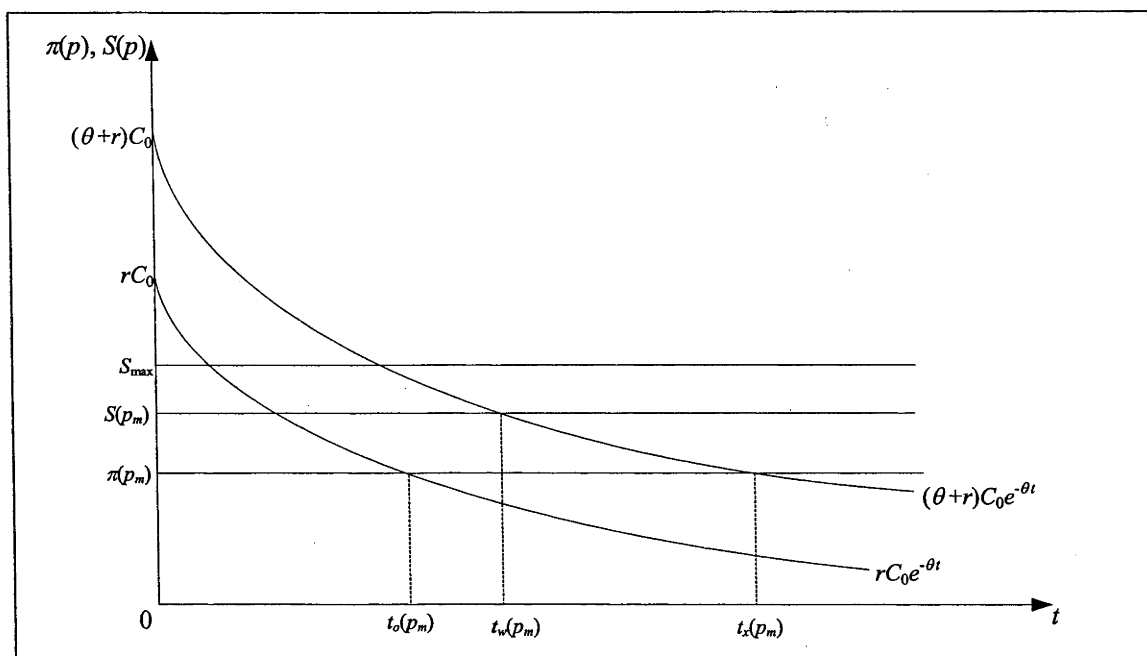
$$t_o(p_m) = \frac{1}{\theta} \log \left( \frac{r C_0}{\pi(p_m)} \right) \quad (7.2.10)$$

This investment timing  $t_o(p_m)$  is earlier than that of the monopoly investor, and may now occur before, at, or after the dynamically-efficient time  $t_w(p_m)$ . From the analysis in Section 6.3:

- if  $\frac{CS(p_m)}{\pi(p_m)} > \frac{\theta}{r}$ , the investment is inefficiently delayed (i.e.  $t_o(p_m) > t_w(p_m)$ );
- if  $\frac{CS(p_m)}{\pi(p_m)} = \frac{\theta}{r}$ , the investment is undertaken at the dynamically-efficient time; and
- if  $\frac{CS(p_m)}{\pi(p_m)} < \frac{\theta}{r}$ , there is premature investment in infrastructure (i.e.  $t_o(p_m) < t_w(p_m)$ ).

Figure 7.2.3 illustrates an instance where the essential infrastructure is provided too early at the linear access price  $p_m$ .

FIGURE 7.2.3 TIMING OF A COMPETITIVE OR ROR-REGULATED MONOPOLY INVESTOR



As the net present value to the firm is zero, the positive net benefits of the investment are derived entirely by the consumer. Substituting price  $p_m$  into the expression for the net present to society given by Table 6.3.1, or in equation (6.2.17), yields

$$NPV_s^o(p_m) = \frac{1}{r} (CS(p_m)) \left( \frac{\pi(p_m)}{rC_0} \right)^{\frac{r}{\theta}} \quad (7.2.11)$$

The PC (2001b) highlights the potential for a similar type of outcome to that outlined here in Section 7.2.2, when it states (at page 71):

Competition at the construction phase will sometimes occur against a back-drop of the potential for the successful investor to charge monopoly prices once it has become established as the incumbent provider.

Further, the PC recognises that perfect competition to construct to investment:

...might sometimes lead to premature investment in capacity, but still with some degree of monopoly pricing of the services concerned.

However, unlike the framework used here, it appears that in considering investment timing, the Productivity Commission linked a unique price with a specific rate of return that was allowed on the investment.

### 7.2.3 Comparing Benefits to Society Derived by the Investors

When allowed to charge a linear access price, the unregulated monopoly and unregulated competitive (or ROR-regulated monopoly) investor, both create the same level of allocative inefficiency. Therefore, the overall net present value derived by society will depend upon the level of dynamic efficiency achieved by each investor.

Using the work done in Section 6.3, the competitive or ROR-regulated monopoly investor achieves a higher level of dynamic efficiency and net present value to society than the unregulated monopoly investor, if there is either:

- inefficient delay of the investment (i.e.  $t_x(p_m) > t_o(p_m) > t_w(p_m)$ ); or
- the investment occurs at the socially-optimal time (i.e.  $t_o(p_m) = t_w(p_m)$ ).

Such outcomes will arise when  $\frac{CS(p_m)}{\pi(p_m)} \geq \frac{\theta}{r}$ .

The net present value to society generated by the competitive or ROR-regulated monopoly investor may only be less than or equal to that generated by the monopoly investor, if the investment is undertaken prior to the socially-optimal time (i.e.  $t_o(p_m) <$

$t_w(p_m)$ ). This occurs if  $\frac{CS(p_m)}{\pi(p_m)} < \frac{\theta}{r}$ .

A comparison of the net present value to society achieved by the competitive, ROR-regulated and unregulated monopoly investor, and its dependence upon the rate of cost-decreasing technological progress  $\theta$ , is explored more thoroughly in the numerical calculations and graphs done in Section 7.5.

### 7.3 Linear Access Price Regulation of a Monopoly Investor

This Section examines the outcome to society when the regulator can only set the maximum usage price for the monopoly investor earning the rate of return  $\theta + r$ . By establishing that some price regulation of the monopoly investor does increase welfare, a condition is found that the optimal linear access price  $p_x^*$  must satisfy. This price maximises the net present value to society achieved by the monopoly investor, by maximising the trade-off outlined to occur between allocative and dynamic efficiency in Section 6.4.2. It also established that the optimal price  $p_x^*$ , will be lower, the higher rate of technological progress  $\theta$  is. Finally, some policy implications of the results established here are outlined.

#### 7.3.1 Does Price Regulation of A Monopoly Investor Increase Welfare?

To assess whether linear price regulation of the monopoly investor earning the rate of return  $\theta + r$  is beneficial, it is necessary to examine if a small decrease in the usage price from  $p_m$ , increases the net present value to society.

From Table 6.3.1 or equation (6.2.13), the net present value to society derived by a monopoly investor given a zero fixed fee, is

$$NPV_s^x(p) = \frac{1}{r} \left( \frac{\theta S(p) + rCS(p)}{\theta + r} \right) \left( \frac{\pi(p)}{(\theta + r)C_0} \right)^{\frac{1}{\theta}} \quad (7.3.1)$$

Taking the first derivative of equation (7.3.1) yields,

$$\frac{dNPV_s^x}{dp} = \frac{1}{r} \left( \frac{1}{\theta + r} \right) \left( \theta S'(p) + rCS'(p) + \frac{(\theta S(p) + rCS(p))r\pi'(p)}{\theta\pi(p)} \right) \left( \frac{\pi(p)}{(\theta + r)C_0} \right)^{\frac{1}{\theta}} \quad (7.3.2)$$

There is an increase in the net present value to society from a small amount of price regulation, if equation (7.3.2) evaluated at price  $p_m$  is less than zero. As by assumption  $\pi'(p_m) = 0$  and  $CS'(p_m), S'(p_m) < 0$ , the resulting expression and sign for the derivative evaluated at price  $p_m$  is,

$$\left. \frac{dNPV_s^x}{dp} \right|_{p=p_m} = \frac{1}{r} \left( \frac{1}{\theta + r} \right) \left( \frac{\pi(p_m)}{(\theta + r)C_0} \right)^{\frac{1}{\theta}} (\theta S'(p_m) + rCS'(p_m)) < 0 \quad (7.3.3)$$

The outcome in equation (7.3.3) highlights that a small amount of price regulation of the monopoly investor will increase the benefit to society. Based on the analysis in Section 6.4.2, it can be concluded here that for a small decrease in the price from  $p_m$ , the additional benefit resulting from the lower cost and higher social surplus, exceeds the additional cost resulting from the increased inefficient delay.

### 7.3.2 The Linear Access Price that Maximises Benefits to Society

The result in Section 7.3.1 suggests that the optimal linear access price set by the regulator  $p_x^*$  will:

- lie below the unregulated monopoly price  $p_m$ ; and
- equate the marginal cost associated with increased delay, with the marginal benefit resulting from the decrease in cost and increase in allocative efficiency.

To find the optimal usage price for access that should be set by a monopoly investor earning the rate of return  $\theta + r$ , the following maximisation is done.

$$\max_p NPV_s^x(p) = \frac{1}{r} \left( \frac{\theta S(p) + rCS(p)}{\theta + r} \right) \left( \frac{\pi(p)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}}, \text{ where } p_m > p > 0 \quad (7.3.4)$$

Using the derivative in equation (7.3.2), the FOC is then

$$\left. \frac{dNPV_s^x}{dp} \right|_{p=p_x^*} = \frac{1}{r} \left( \frac{1}{\theta + r} \right) \times \left( \theta S'(p) + rCS'(p) + \frac{(\theta S(p) + rCS(p))r\pi'(p)}{\theta\pi(p)} \right) \left( \frac{\pi(p)}{(\theta + r)C_0} \right)^{\frac{r}{\theta}} = 0 \quad (7.3.5)$$

Solving this, the condition that must be satisfied at price  $p_x^*$  is,

$$-\frac{CS(p_x^*)}{\pi(p_x^*)} \cdot \frac{\pi'(p_x^*)}{S'(p_x^*)} = \frac{\theta}{r} \quad (7.3.6)^7$$

The derivation of the expression in equation (7.3.6) is outlined in the Appendix of the Chapter, in Section A.7.1.

<sup>7</sup> If  $\varepsilon_d$  denotes the price elasticity of demand such that,  $\varepsilon_d = -p \cdot q' / q$ , it follows that, equation (7.3.6) can be expressed as,

$$\frac{CS(p_x^*)}{\pi(p_x^*)} \left( \frac{1 - \varepsilon_d(p_x^*)}{\varepsilon_d(p_x^*)} \right) = \frac{\theta}{r}$$

From equation (7.3.6) it appears that the optimal regulated price  $p_x^*$ , which maximises the net present value to society achieved by a monopoly investor, depends upon:

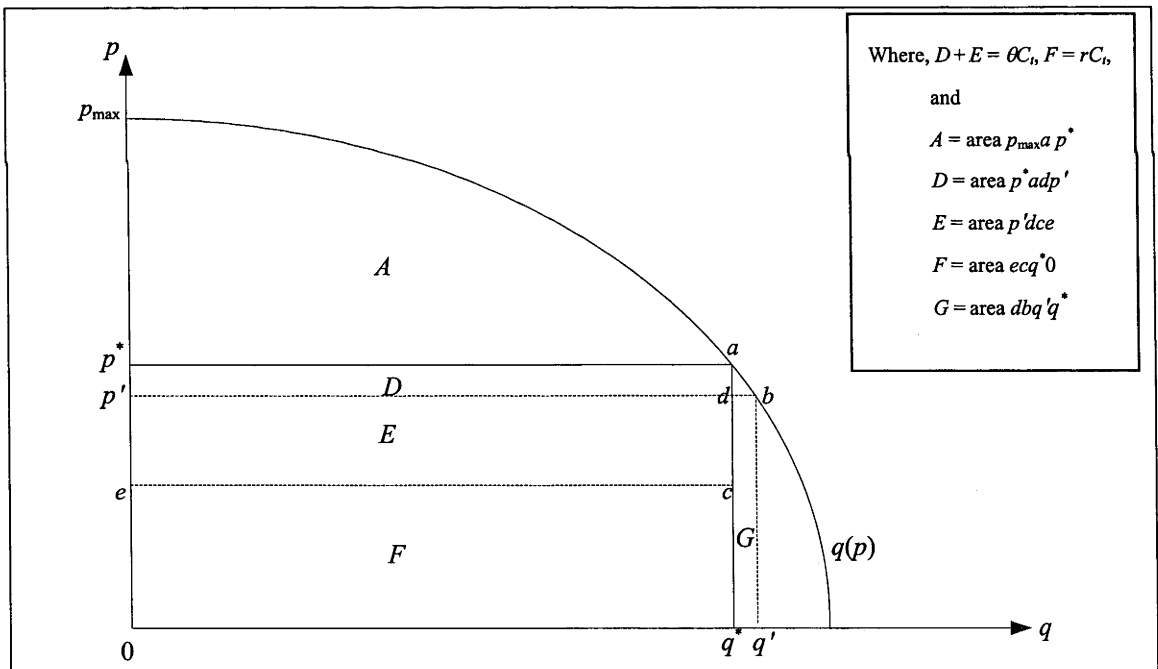
- the relative value of the rate of cost-decreasing technological progress  $\theta$ , to the normal rate of return on capital  $r$  (i.e.  $\theta/r$ ); and
- the demand curve for access.

Given some specific functional form for the demand curve for access, it is possible to solve equation (7.3.6) for the optimal linear access price  $p_x^*$ . This is done in the numerical example outlined in Section 7.5.

### 7.3.3 A Simple Method for Deriving the Optimal Condition in Equation (7.3.6)

To provide a simple intuitive derivation for the optimal condition in equation (7.3.6), Figure 7.3.1 is used, along with the assumption of discrete time. The advantage of this method is that it does not involve the complex maximisation of Section 7.3.2.<sup>8</sup>

**FIGURE 7.3.1 DERIVING THE OPTIMAL CONDITION IN EQUATION (7.3.6)**



By investing at some time  $t$ , it has been established that the monopoly investor earns a revenue flow in each period of  $(\theta + r)C_t$ . In Figure 7.3.1 therefore,

<sup>8</sup> Thank you to Ben Smith and my Supervisor for outlining this simple method for deriving the optimal condition.

$$D + E + F = (\theta + r)C_t = p^* q^* \quad (7.3.7)$$

If the regulator decreases the price marginally so that the monopoly investor delays the investment for one period, the essential facility is provided at time  $t + 1$ . In Figure 7.3.1, this small decrease in price from  $p^*$  to  $p'$  leads to the firm losing revenue equal to the horizontal sliver of area  $D$ , but gaining revenue equal to the vertical sliver of area  $G$ . Subsequently, the firm investing at time  $t + 1$  earns an amount of revenue in each period of  $(\theta + r)C_{t+1} = p'q'$ , which is captured in the diagram by area  $D + E + F - D + G$ . As with discrete time and the cost-decreasing rate of technological progress  $\theta$ ,  $C_{t+1}$  is equal to  $C_t(1 - \theta)$ , the monopoly investor now earns revenue in each period of,

$$D + E + F - D + G = (\theta + r)C_t(1 - \theta) \quad (7.3.8)$$

From equation (7.3.7) and (7.3.8), it follows that a decrease in the access price, which defers the investment by the firm for one period, yields an expression for the rate of technological progress of,

$$\theta = \frac{D - G}{D + E + F} \quad (7.3.9)$$

The net benefit to society from decreasing price  $p$  and deferring the investment until time  $t + 1$ , is comprised of:

- the present value of the additional social benefit derived from delay; plus
- the cost saving from delay; minus
- the foregone social surplus from delay.

As the additional benefit to society from deferring the investment one period is captured in Figure 7.3.1 by area  $G$ , the present value of the social benefits from investing at time  $t + 1$  will be equal to  $G/r$ . The cost saving from deferring the investment for one period consists of the decrease in cost due to technological progress (i.e.  $\theta C_t$ ), and the capital costs that are no longer foregone (i.e.  $rC_t$ ). The term  $(\theta + r)C_t$  is depicted in Figure 7.3.1 by the area  $D + E + F$ . Finally, the lost social surplus from delaying the investment until time  $t + 1$  is illustrated in Figure 7.3.1 by the area  $A + D + E + F$ . Consequently, the net benefit to society ( $NB_s$ ) at time  $t + 1$ , from decreasing the price and delaying the investment is equal to,

$$NB_s = \frac{G}{r} + (D + E + F) - (A + D + E + F) = \frac{G}{r} - A \quad (7.3.10)$$



The value of the investment to society achieved by a monopoly investor is maximised, where the net benefit to society is equal to zero. Setting equation (7.3.10) equal to zero and solving, the expression derived for the rate of return  $r$  at the socially-optimal price  $p_x^*$  is,

$$r = \frac{G}{A} \quad (7.3.11)$$

From equation (7.3.9) and equation (7.3.11), it follows that for the monopoly investor earning the rate of return  $\theta + r$ , the value of the investment to society is maximised, if price  $p_x^*$  is set so that it satisfies the condition,

$$\frac{\theta}{r} = \frac{(D - G)/D + E + F}{G/A} = \frac{A}{D + E + F} \left( \frac{D - G}{G} \right) \quad (7.3.12)$$

By recognising here that:

- $A$  represents the level of consumer surplus at price  $p_x^*$ , i.e.  $CS(p_x^*)$ ;
- $G$  is the change in social surplus with respect to a change in the price evaluated at  $p_x^*$ , i.e.  $S'(p_x^*)dp$ ;
- $G - D$  is the change in revenue with respect to a change in price evaluated at  $p_x^*$ , i.e.  $\pi'(p_x^*)dp$ ; and
- $D + E + F$  represents the total revenue at  $p_x^*$ , i.e.  $\pi(p_x^*)$ ;

it follows that the expression in equation (7.3.12), is identical to the optimal condition given by equation (7.3.6). That is,

$$\frac{A}{D + E + F} \left( \frac{D - G}{G} \right) = - \frac{CS(p_x^*)}{\pi(p_x^*)} \cdot \frac{\pi'(p_x^*)}{S'(p_x^*)} = \frac{\theta}{r}$$

#### 7.3.4 Technological Progress, the Rate of Return and the Optimal Price

The optimal condition the access price must satisfy in equation (7.3.6), suggests that the value of  $p_x^*$ , depends upon the relative value of the rate of cost-decreasing technological progress  $\theta$ , and the normal rate of return on capital  $r$  (i.e.  $\theta/r$ ). Although an expression for  $p_x^*$  cannot be derived without a specific demand curve, it is still possible to assess

the relationship between  $p_x^*$  and  $\theta/r$ . To do this, the total differential of equation (7.3.6) is taken, and an expression is derived for  $dp_x^*/d(\frac{\theta}{r})$ . This yields,

$$\frac{dp_x^*}{d(\frac{\theta}{r})} = \frac{-\pi(p_x^*) \left[ \frac{S'(p_x^*)}{\pi'(p_x^*)} \right]}{\underbrace{CS'(p_x^*)}_{<0} + \underbrace{\frac{\theta S'(p_x^*)}{r}}_{<0} + \underbrace{\frac{\theta \pi(p_x^*)}{r}}_{>0} \underbrace{\left[ \frac{\pi'(p_x^*) S''(p_x^*) - S'(p_x^*) \pi''(p_x^*)}{\pi'(p_x^*)^2} \right]}_{<0}} < 0 \quad (7.3.13)^9$$

The working to derive the expression in equation (7.3.13) is outlined in the Appendix of Chapter 7, in Section A.7.2.

As the expression in equation (7.3.13) is less than zero, the higher the rate of technological progress is relative to the rate of return, the lower is the optimal liner regulated price  $p_x^*$  that is charged by the monopoly investor. The outcome suggests that, the higher the rate of technological progress is, the higher will be the marginal benefit relative to the marginal cost of any given decrease in the access price.

### 7.3.5 Policy Implications of the Results

#### 7.3.5.1 Benefits from 'Anticipatory Retardation'

As outlined in Chapter 4, Kahn et al. (1999) cited the work of Fellner (1958) to highlight the problem of "anticipatory retardation" in industries experiencing continual technological progress. This involves the firm only adopting the most modern technology when the progressively decreasing costs have fallen to a level where, the prevailing price allows the investor achieve a given rate of return on the asset. In this model though, it is shown that while price regulation will induce the monopoly investor to defer the investment — i.e. until the lower regulated price allows the firm to earn the monopoly rate of return  $\theta + r$  — this delay can be beneficial for society. This is the case if the cost of delaying the investment is offset by the gains from the lower price that is

<sup>9</sup> It should be noted that this outcome is true for a non-convex demand curve. It has not been shown here that this result will hold more generally.

paid by the consumer when the access is provided. Kahn et al. do not appear to consider these potential benefits that may arise from delay or “anticipatory retardation”.

### 7.3.5.2 *The Contrasting Impact of Price and ROR Regulation*

As the price-regulated investor still earns the rate of return on the investment  $\theta + r$ , it must retain its market power in providing the essential infrastructure. Therefore, in this framework, where there is a constant rate of cost-decreasing technological progress, price and ROR regulation, which are sometimes argued to have similar impacts upon the firm in static models,<sup>10</sup> yield very different outcomes for the monopoly investor.

As shown in Section 6.5, in this framework, ROR regulation of the monopoly investor simulates the effects of having competition to become the essential infrastructure provider i.e. “competition for the market”. In contrast, price regulation simulates the effects of “competition in the market”, once the essential infrastructure has been provided. Therefore, although the optimal usage price has some impact upon the investment timing by the monopoly investor, the regulator is effectively, only imposing market discipline upon the firm after the investment has been undertaken.

As ROR and price regulation simulate very different competitive effects, it is not surprising that the two forms of regulation have a very different impact upon investment timing. As Section 7.2 illustrates, merely restricting the rate of return decreases the delay of the investment by the monopoly investor, yet has no effect on allocative efficiency. In contrast, price regulation causes the monopoly investor to further delay the investment, but increases the level of allocative efficiency.

The issue of whether ROR or price regulation of the monopoly investor generates a better outcome for society is difficult to assess. However, it can be inferred that because price regulation of the monopoly investor induces greater benefits for society than no regulation, similar results will hold to those outlined in Section 6.5. That is, with a higher rate of technological progress, it more likely that a ROR-regulated monopoly investor will induce worse outcomes for society than a price-regulated monopoly investor that earns the rate of return  $\theta + r$ . The numerical example in Section 7.5 highlights this result.

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<sup>10</sup> For example see Rees and Vickers (1995).

#### 7.3.5.3 *The 'Access Holiday'*

The result in equation (7.3.13) suggests that, where an industry is subject to rapid rate of technological progress, there is less scope for an investor to be granted an access holiday and allowed to charge price  $p_m$  for some period of time. This point was also raised in Section 6.6, and was shown to be consistent with recommendations made by the Productivity Commission.

#### 7.3.5.4 *Difficulties of Setting the Optimal Price*

The analysis here suggests that in order to set the optimal access price of  $p_x^*$ , the regulator must have information about:

- the rate of technological progress  $\theta$ , and
- the industry demand curve, so that it can estimate the consumer surplus and operating profit in each period.

In practice, in determining the appropriate access price, regulators use and have access to estimates of the levels of technological progress, demand and elasticity of demand. However, they do not appear to go further, and explicitly estimate a demand curve for the industry. Such information may be difficult to obtain, and to some extent may limit the ability to implement the type of access price that is recommended here. Nevertheless, the results here raise issues that regulators may need to be aware of, or take into account, when regulating linear prices in industries experiencing rapid rates of cost-decreasing technological progress.

## 7.4 Linear Price Regulation of the Competitive Investor/Linear Price and ROR Regulation of the Monopoly Investor

This Section examines the effect of linear access price regulation on a competitive investor, or alternatively, based on the analysis in Section 6.5, the combination of price and ROR regulation on a monopoly investor. The analysis here is very similar to that done in the previous Section. Subsequently, it is initially established that some price regulation of the investor is optimal, before a condition is found that the optimal price  $p_o^*$  must satisfy. It is shown that while this optimal price may increase both allocative and dynamic efficiency, it will never be dynamically efficient. This suggests that as in the analysis of Evans, Quigley and Zhang (EQZ, 2003), the optimal linear price  $p_o^*$  can be thought of as a “second-best” efficient price. It is also shown that as with the optimal price for the monopoly investor, the optimal price here will be lower, the higher rate of technological progress  $\theta$  is. Finally, policy implications of the results are examined.

### 7.4.1 Does Price Regulation Increase Welfare?

As in the previous Section, to establish whether price regulation of the competitive investor or ROR-regulated monopoly investor is beneficial, it is necessary to examine if a small decrease in price from  $p_m$ , increases the net present value to society.

From Table 6.3.1 or equation (6.2.17), the net present value to society derived by a competitive investor given a zero fixed fee is,

$$NPV_s^o(p) = \frac{1}{r} (CS(p)) \left( \frac{\pi(p)}{rC_0} \right)^{\frac{\epsilon}{\epsilon-1}} \quad (7.4.1)$$

Taking the derivative of equation (7.4.1) with respect to  $p$ ,

$$\frac{dNPV_s^o}{dp} = \frac{1}{r} \left( \frac{\pi(p)}{rC_0} \right)^{\frac{\epsilon}{\epsilon-1}} \left( \frac{\theta\pi(p)CS'(p) + rCS(p)\pi'(p)}{\theta\pi(p)} \right) \quad (7.4.2)$$

As by assumption  $\pi'(p_m) = 0$  and  $CS'(p_m) < 0$ , evaluating equation (7.4.2) at price  $p_m$ , yields the following expression and sign for the derivative.

$$\left. \frac{dNPV_s^o}{dp} \right|_{p=p_m} = \frac{1}{r} \left( \frac{\pi(p_m)}{rC_0} \right)^{\frac{\epsilon}{\epsilon-1}} CS'(p_m) < 0 \quad (7.4.3)$$

This indicates that some level of price regulation of the competitive investor is beneficial for society.

#### 7.4.2 The Linear Access Price that Maximises Benefits to Society

With competition for the investment, the optimal usage price is found by undertaking the following maximisation,

$$\max_p NPV_s^o(p) = \frac{1}{r} (CS(p)) \left( \frac{\pi(p)}{rC_0} \right)^{\frac{r}{\theta}}, \text{ where } p_m > p > 0 \quad (7.4.4)$$

Using the derivative in equation (7.4.2), the FOC is then,

$$\left. \frac{dNPV_s^o}{dp} \right|_{p=p_o^*} = \frac{1}{r} \left( \frac{\pi(p)}{(\theta+r)C_0} \right)^{\frac{r}{\theta}} \left( \frac{\theta\pi(p)CS'(p) + rCS(p)\pi'(p)}{\theta\pi(p)} \right) = 0 \quad (7.4.5)$$

Solving this, the condition the optimal price  $p_o^*$  must satisfy is,

$$-\frac{CS(p_o^*)}{\pi(p_o^*)} \cdot \frac{\pi'(p_o^*)}{CS'(p_o^*)} = \frac{\theta}{r} \quad (7.4.6)^{11}$$

Using  $\eta_\pi$  to denote the price elasticity of revenue and  $\eta_{CS}$  to denote the price elasticity of consumer surplus, it follows that equation (7.4.6) can be simplified to give,

$$\frac{\eta_\pi(p_o^*)}{\eta_{CS}(p_o^*)} = \frac{\theta}{r}, \quad (7.4.7)$$

$$\text{where } \eta_\pi(p) = \frac{\pi'(p) \cdot p}{\pi(p)} \text{ and } \eta_{CS}(p) = -\frac{CS'(p) \cdot p}{CS(p)}$$

Therefore, at the optimal price, the percentage change in revenue divided by the percentage change in consumer surplus must be equal to the rate of technological progress divided by the rate of return on capital. This implies that, as was the case for the price-regulated monopoly investor, the optimal price  $p_o^*$  for a competitive investor or ROR-regulated monopoly investor, depends upon:

<sup>11</sup> As in Section 7.3 the optimal condition in equation (7.4.6) can be expressed in terms of the price elasticity of demand  $\varepsilon_d$ , which

yields,  $\frac{CS(p_o^*)}{\pi(p_o^*)} (1 - \varepsilon_d(p_o^*)) = \frac{\theta}{r}$ .

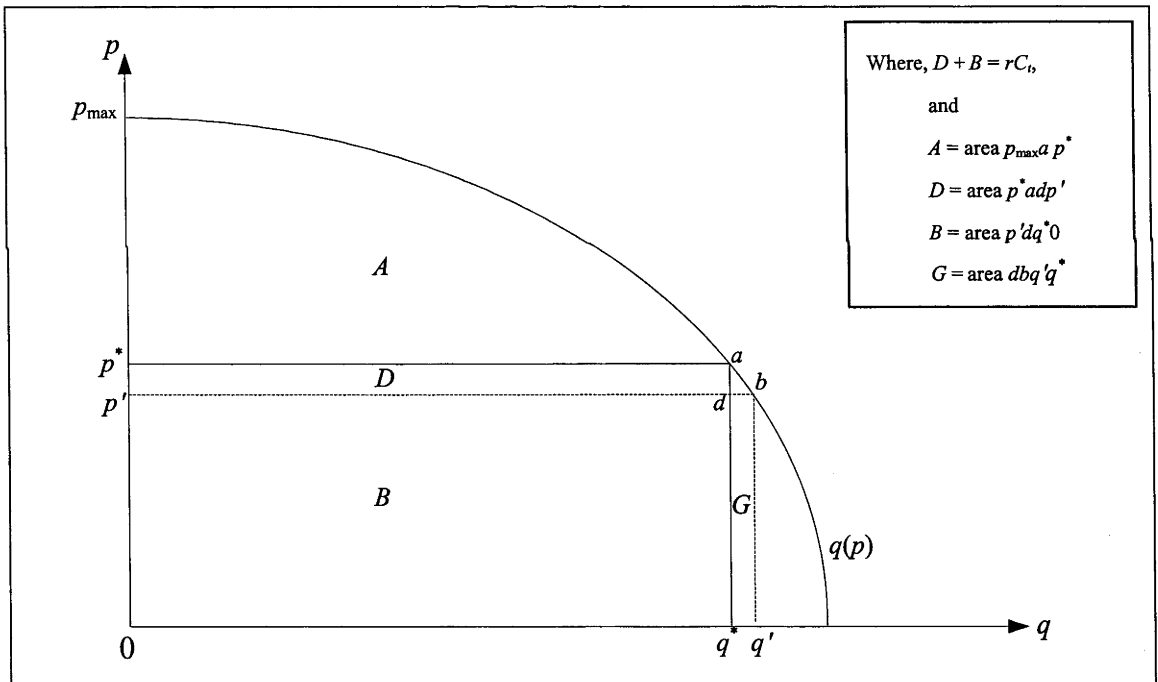
- the ratio of the rate of cost-decreasing technological progress to the rate of return on capital (i.e.  $\theta/r$ ); and
- the demand curve for access.

Given some specific functional form for the demand curve for access, it would be possible to solve for the regulated linear price  $p_o^*$  that maximises the net present value to society achieved by the competitive investor.

#### 7.4.3 A Simple Method for Deriving the Optimal Condition in Equation (7.4.6)

As in Section 7.3.3, a simple intuitive derivation for the optimal condition given by equation (7.4.7) is outlined here. Once again the assumption of discrete time is used along with information from a price-quantity space diagram, which is illustrated in Figure 7.4.1.<sup>12</sup>

**FIGURE 7.4.1 DERIVING THE OPTIMAL CONDITION IN EQUATION (7.4.6)**



By investing at time  $t$ , the ROR-regulated monopoly investor, or the competitive investor, generates a revenue flow in each period of  $rC_t$ . From Figure 7.4.1 therefore,

$$D + B = rC_t = p^* q^* \quad (7.4.8)$$

<sup>12</sup> As with Section 7.3.3, Ben Smith and my Supervisor outlined this simple method for deriving the optimal condition.

If the regulator decreases the price marginally so that the competitive investor delays the investment for one period, then the essential facility is provided at time  $t + 1$ . In Figure 7.4.1, the small decrease in price from  $p^*$  to  $p'$  that induces such a delay, leads to the firm losing revenue equal to the horizontal sliver of area  $D$ , but gaining revenue equal to the vertical sliver of area  $G$ . Subsequently, the firm investing at time  $t + 1$  earns revenue of  $B - D + G$ , which is equal to  $rC_{t+1}$ . As with discrete time,  $C_{t+1}$  is equal to  $C_t(1 - \theta)$ , it follows that the ROR-regulated monopoly or competitive investor providing the infrastructure at time  $t + 1$ , earns revenue in each period of,

$$B - D + G = rC_t(1 - \theta) = p'q' \quad (7.4.9)$$

Substituting equation (7.4.8) into (7.4.9), it follows that a decrease in the access price, which induces the firm to defer the investment for one period, yields an expression for the rate of technological progress of,

$$\theta = \frac{D - G}{D + B} \quad (7.4.10)$$

The net benefit to society of decreasing the usage price  $p$  and deferring the investment until time  $t + 1$ , consists of:

- the present value of the additional social benefit derived from delay, plus
- the cost saving from delay; minus
- the foregone social surplus from delay.

As the additional benefit to society from decreasing the price and deferring the investment until time  $t + 1$  is captured in Figure 7.4.1 by area  $G$ , the present value of the benefits will be equal to  $G/r$ . The cost saving to society from deferring the investment for one period is  $(\theta + r)C_t$ , which from equation (7.4.8) and equation (7.4.10) is equal to  $D + B + (D - G)/r$ . Meanwhile, the cost of foregoing surplus and delaying the investment for one period is illustrated in Figure 7.4.1 by area  $A + D + B$ . Consequently, the net benefit to society ( $NB_s$ ) at time  $t + 1$  from decreasing the price and deferring the investment is,

$$NB_s = \frac{G}{r} + \left( D + B + \frac{D - G}{r} \right) - (A + D + B) = \frac{D}{r} - A \quad (7.4.11)$$

The value of the investment to society achieved by the competitive, or ROR-regulated monopoly investor, is maximised if the net benefit to society resulting from the decrease in price and subsequent one period delay, is equal to zero. Therefore, setting equation



(7.4.11) equal to zero and solving, the expression derived for the rate of return  $r$  at the optimal linear access price  $p_o^*$  is,

$$r = \frac{D}{A} \quad (7.4.12)$$

From equations (7.4.10) and (7.4.12), the value of the investment to society is maximised, if a price  $p_o^*$  is set so that it satisfies the following condition,

$$\frac{\theta}{r} = \frac{(D - G)/D + B}{D/A} = \frac{A}{D + B} \left( \frac{D - G}{D} \right) \quad (7.4.13)$$

By recognising here that:

- $A$  represents the level of consumer surplus at price  $p_o^*$ , i.e.  $CS(p_o^*)$ ;
- $D$  is the change in consumer surplus with respect to a change in the price, evaluated at price  $p_o^*$ , i.e.  $CS'(p_o^*)dp$ ;
- $G - D$  is the change in revenue with respect to a change in price evaluated at price  $p_o^*$ , i.e.  $\pi'(p_o^*)dp$ ; and
- $D + B$  represents the total revenue flow to the firm at price  $p_o^*$ , i.e.  $\pi(p_o^*)$ ;

it follows that the expression in equation (7.4.13), will be identical to the optimal condition of equation (7.4.7). That is,

$$\frac{A}{D + B} \left( \frac{D - G}{D} \right) = - \frac{CS(p_o^*)}{\pi(p_o^*)} \frac{\pi'(p_o^*)}{CS'(p_o^*)} = \frac{\eta_\pi(p_o^*)}{\eta_{CS}(p_o^*)} = \frac{\theta}{r}$$

#### 7.4.4 Is the Optimal Linear Access Price Dynamically Efficient?

The analysis in Section 6.4.2 suggests that if the competitive investor at price  $p_m$  is investing after the socially-optimal time (i.e.  $t_o(p_m) < t_w(p_m)$ ), then there is a dynamic and static allocative efficiency trade-off associated with a decrease in the usage price. This implies that at  $p_o^*$ , the investment always occurs at a later time than the dynamically-efficient time associated with price  $p_o^*$  (i.e.  $t_o(p_o^*) < t_w(p_o^*)$ ). In contrast, if the competitive investor at price  $p_m$  invests after the socially-optimal time (i.e.  $t_o(p_m) > t_w(p_m)$ ), then a decrease in the usage price can potentially increase both dynamic and static allocative efficiency. As Section 6.4.2 shows, it is even possible that with an appropriate decrease in the usage price, a dynamically-efficient time can be achieved.

The question here is, where it is possible for an increase in dynamic and static efficiency to occur, does the regulator maximise the net present value to society by setting an access price that is dynamically efficient? To answer this, the condition that the optimal regulated price must satisfy in equation (7.4.6), is compared with the condition that the access price associated with dynamically-efficient time must satisfy in equation (6.4.3).

With a zero fixed fee, the competitive investor is dynamically efficient if it charges the access price  $p_d^*$  that satisfies the condition,

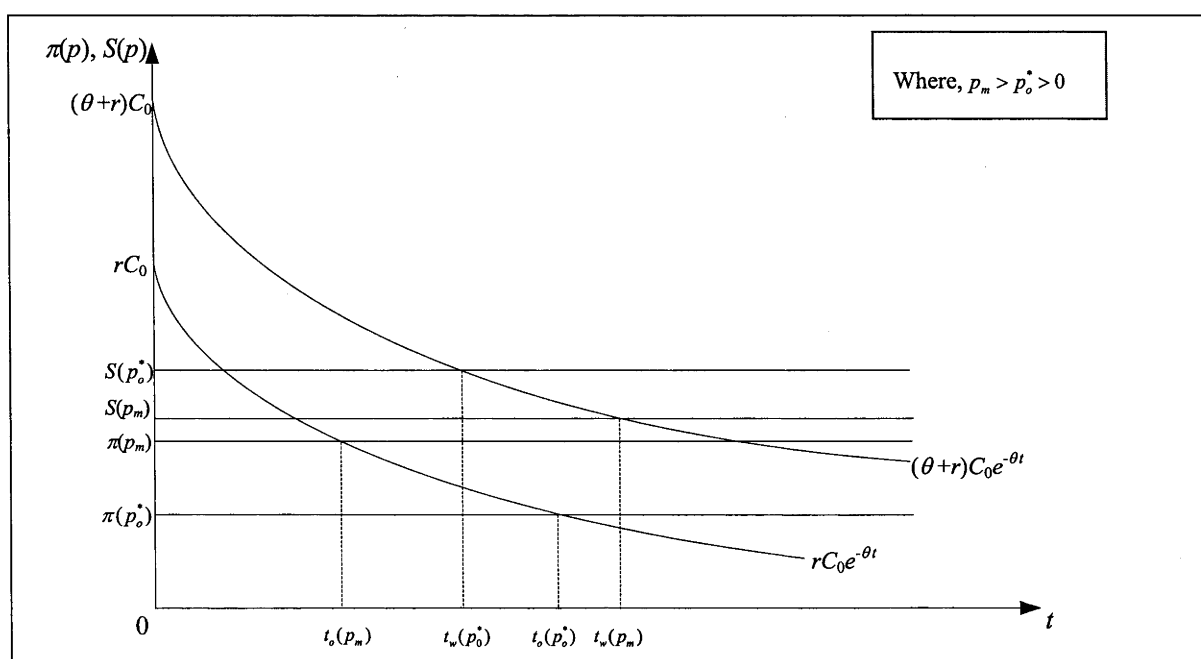
$$\frac{CS(p_d^*)}{\pi(p_d^*)} = \frac{\theta}{r} \quad (7.4.14)$$

As in equation (7.4.6),

$$-\frac{CS'(p_o^*)}{\pi'(p_o^*)} = \frac{q(p_o^*)}{q(p_o^*) + p_o \cdot q'(p_o^*)} > 1, \text{ where } p_m > p_o^* > 0 \quad (7.4.15)$$

it follows that the outcome in equation (7.4.14) is not the same as the optimal condition in equation (7.4.16). This implies that  $p_o^*$  is not equal to  $p_d^*$ . Consequently, even in instances where there is the potential for an investor to experience a gain in both allocative and dynamic efficiency, the linear access price that maximises the net present value to society will always be dynamically inefficient. The dynamic inefficiency of the optimal price  $p_o^*$  is depicted in Figure 7.4.2.

**FIGURE 7.4.2 THE USAGE PRICE AND DYNAMIC EFFICIENCY UNDER COMPETITION**



Therefore, given the existing distortion that arises from the allocative inefficiency generated by linear price regulation, it is **not** optimal to set a price that achieves the dynamically-efficient outcome. The idea that an efficient outcome does not maximise welfare given an existing distortion, is similar to the idea in the theory of second best. Subsequently, the regulated linear access price  $p_o^*$  that maximises the net present value to society can be thought of as either, a second-best-efficient price or a dynamic Ramsey-Boiteux price. Further, as the optimal linear price is above the allocatively-efficient-short-run marginal cost and below the monopoly price  $p_m$ , it has similar properties to the optimal wholesale market price found in the analysis of EQZ (2003).

#### 7.4.5 Technological Progress, the Rate of Return and the Optimal Price

As in Section 7.3.4, it is possible to assess the relationship between  $p_o^*$  and  $\theta/r$  here, by taking the total differential of the equation for the optimal condition, and deriving an expression for  $dp_o^*/d(\frac{\theta}{r})$ . This yields,

$$\frac{dp_o^*}{d(\frac{\theta}{r})} = \frac{\overbrace{-\pi(p_o^*)}^{>0} \left[ \frac{CS'(p_o^*)}{\pi'(p_o^*)} \right]}{\underbrace{CS'(p_o^*)}_{<0} \left( 1 + \frac{\theta}{r} \right) + \underbrace{\frac{\theta \pi(p_o^*)}{r}}_{>0} \left[ \frac{\overbrace{\pi'(p_o^*)CS''(p_o^*) - CS'(p_o^*)\pi''(p_o^*)}^{?}}{\underbrace{\pi'(p_o^*)^2}_{>0}} \right]} \quad (7.4.16)$$

The working for this outcome is provided in the Appendix of Chapter Seven in Section A.7.3.

Here, the sign of  $dp_o^*/d(\frac{\theta}{r})$  depends upon the sign of,

$$\pi'(p_o^*)CS''(p_o^*) - CS'(p_o^*)\pi''(p_o^*)$$

From the assumptions outlined in Section 6.2.1,

$$\pi'(p_o^*)CS''(p_o^*) - CS'(p_o^*)\pi''(p_o^*) = \underbrace{q(p_o^*)}_{>0} \underbrace{q'(p_o^*)}_{<0} - \underbrace{p_o^*[q'(p_o^*)]^2}_{>0} + \underbrace{p_o^*q(p_o^*)}_{>0} \underbrace{q''(p_o^*)}_{\leq 0} < 0$$

This implies the square-bracketed term in the denominator of equation (7.4.16) is less than zero, and that the expression for  $dp_o^*/d(\frac{\theta}{r})$  is less than zero. This suggests, that as with the monopoly investor in Section 7.3.4, the higher the rate of technological

progress is, the higher will be the marginal benefit relative to the marginal cost that results for any given decrease in the access price.<sup>13</sup>

#### 7.4.6 Policy Implications of the Results

As the results here are similar to those found in the previous Section, there are similar policy implications. That is, with constantly decreasing costs over time: the anticipatory retardation that results from a lower access may be beneficial to society; there is less of a case for an access holiday when there is a higher rate of technological progress; and there are obviously difficulties in setting the optimal price for the competitive or ROR-regulated monopoly investor due to the need to estimate the demand curve for access. The results here also provide some additional insights into the optimal regulated price for the competitive or ROR-regulated investor, which may need to be taken into account by the regulator.

##### 7.4.6.1 *Setting the Optimal Regulated Price*

Regulatory authorities often place emphasis on setting an access price that is consistent with achieving an allowed rate of return on an investment of commensurate risk. The result here suggests that in an industry characterised by decreasing costs over time, the regulator must not just allow a firm to charge any access price that achieves the allowed rate of return. The regulator must choose a price, which equates the marginal benefit of a decrease in the price with the marginal cost of deferring the flow of social surplus. In practice, this outcome may be difficult to achieve, due to the information that is required to calculate such a price.

##### 7.4.6.2 *Benefits to Society from "Hybrid" Regulation*

Intuitively, price regulation of the competitive investor or ROR and price regulation of the monopoly investor, should yield the highest level of welfare when a linear access price is charged. The reason for this is that there is now effectively a combination of:

- perfect competition to undertake the investment, i.e. 'competition to construct' or competition 'for' the market; and
- competition 'in' the market, after the essential infrastructure has been provided.

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<sup>13</sup> As in Section 7.3, this result is true for a non-convex demand curve. It has not been shown that this outcome will hold more generally.

For the monopoly investor, the this effect of competition for the market is simulated, by constraining the rate of return the firm is allowed to earn to  $r$ . Once the investment has been made, competition in the market for both the competitive and ROR-regulated monopoly investor is then simulated by the use of price regulation.

The combination of ROR and price regulation has sometimes been referred to as “hybrid” regulation.<sup>14</sup> Contrasting claims have been made that such regulation is ineffective, because:

- price and ROR regulation produce identical results, so any combination of the two is unnecessary; or
- it reintroduces the static inefficiencies of ROR regulation, such as, gold plating, accounting cost padding and the AJ effect.

Although the model here does not assess the impact of such static inefficiencies as the AJ effect or gold plating, it provides an alternative view of hybrid regulation. In this model, with decreasing costs over time, hybrid regulation appears to be effective. ROR regulation of the monopoly investor constrains the market power the firm has to delay the investment, while price regulation places an upper bound on the price the firm can charge once the infrastructure is provided. A comparison of the net present value to society that is generated by each outcome is illustrated using a numerical example in the following Section.

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<sup>14</sup> For example, see Brauetigam and Panzar (1993) and Small (1999) at page 19.

## 7.5 Comparing the Regimes with a Linear Demand for Access

It is assumed here that there is a linear demand curve  $p(q) = a - bq$ , where  $a, b > 0$ , or  $q(p) = (a - p)/b$ . This implies that the consumer surplus and revenue flow in each period is  $CS(p) = (a - p)^2/2b$  and  $\pi(p) = p(a - p)/b$ . By solving for the price under each regime, and evaluating consumer surplus and revenue flow, it is possible to derive expressions for the investment timing, the net present value to the firm and the net present value to society, contained in Table 6.3.1. Assigning values to the parameters, calculations and graphs are done confirming the results established throughout the course of this and the previous Chapter. In particular it is shown that where two-part access tariffs cannot be charged, the highest net present value to society is achieved with price regulation of the competitive investor, or a combination of ROR and price regulation on the monopoly investor.

### 7.5.1 The Socially-Optimal Two-Part Access Tariff

From Section 6.6 the socially-optimal outcome is achieved by setting the usage price of  $p^* = 0$ , and a fixed fee for the monopoly investor of,

$$A_x^* = CS(p^* = 0) = S_{\max} = \frac{a^2}{2b} \quad (7.5.1)$$

and a fixed fee for the competitive or ROR-regulated monopoly investor of,

$$A_o^* = \frac{rCS(p^* = 0)}{\theta + r} = \frac{rS_{\max}}{\theta + r} = \frac{a^2 r}{2b(\theta + r)} \quad (7.5.2)$$

Substituting these access fees into the expression for investment timing in equations (6.6.5) and (6.6.8), yields the dynamically-efficient time,

$$t_x(0, \frac{a^2}{2b}) = t_o(0, \frac{a^2 r}{2b(\theta + r)}) = t_w(0) = \frac{1}{\theta} \log \left( \frac{2b(\theta + r)C_0}{a^2} \right) \quad (7.5.3)$$

The respective access fees ensure that the net present value to society are maximised. From equation (6.6.4) and (6.6.6),

$$NPV_s^w(0) = NPV_f^x(0, \frac{a^2}{2b}) = \frac{1}{r} \left( \frac{a^2 \theta}{2b(\theta + r)} \right) \left( \frac{a^2}{2b(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (7.5.4)$$

### 7.5.2 An Unregulated Linear Access Price

From Section 7.2, as the marginal revenue is  $MR(q) = a - 2bq$  and the short-run marginal cost is zero, an investor not subject to any price regulation, sets the linear price of  $p_m = a/2$ . The resulting consumer surplus, revenue flow and total surplus is then,  $CS(p_m) = a^2/8b$ ,  $\pi(p_m) = a^2/4b$ ,  $S(p_m) = 3a^2/8b$ . Substituting these outcomes into the expression for the socially-optimal investment time in equation (7.2.5), yields

$$t_w(p_m) = \frac{1}{\theta} \log \left( \frac{8b(\theta + r)C_0}{3a^2} \right) \quad (7.5.5)$$

From equations (7.2.4), (7.2.6) and (7.2.7), the investment timing, net present to the firm and society achieved by the monopoly investor will then be,

$$t_x(p_m) = \frac{1}{\theta} \log \left( \frac{4b(\theta + r)C_0}{a^2} \right) \quad (7.5.6)$$

$$NPV_f^x(p_m) = \frac{1}{r} \left( \frac{a^2 \theta}{4b(\theta + r)} \right) \left( \frac{a^2}{4b(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (7.5.7)$$

$$NPV_s^x(p_m) = \frac{1}{r} \left( \frac{a^2 (3\theta + r)}{8b(\theta + r)} \right) \left( \frac{a^2}{4b(\theta + r)C_0} \right)^{\frac{r}{\theta}} \quad (7.5.8)$$

From equations (7.2.10) and (7.2.11), the investment timing and net present value to society achieved by the competitive or ROR-regulated monopoly investor is,

$$t_o(p_m) = \frac{1}{\theta} \log \left( \frac{4brC_0}{a^2} \right) \quad (7.5.9)$$

$$NPV_s^o(p_m) = \frac{1}{r} \left( \frac{a^2}{8b} \right) \left( \frac{a^2}{4brC_0} \right)^{\frac{r}{\theta}} \quad (7.5.10)$$

### 7.5.3 Linear Price Regulation of the Monopoly Investor

In Section 7.3, it was illustrated that if the monopoly investor was allowed to earn the rate of return  $\theta + r$ , the regulator maximises the net present value to society by setting a linear access price that satisfies,

$$-\frac{CS(p_x^*)}{\pi(p_x^*)} \cdot \frac{\pi'(p_x^*)}{S'(p_x^*)} = \frac{\theta}{r}$$

The expression for the derivative of consumer surplus and revenue at any given price  $p$  here is,

$$CS'(p) = -\frac{1}{b}(a - p) \quad (7.5.11a)$$

$$\pi'(p) = \frac{1}{b}(a - 2p) \quad (7.5.11b)$$

Evaluating consumer surplus, the revenue flows and the above derivatives at price  $p_x^*$ , the working outlined in the Appendix A.7.4, shows that the optimal condition yields,

$$(1 - \frac{\theta}{r})p_x^{*2} - (\frac{3a}{2})p_x^* + \frac{a^2}{2} = 0 \quad (7.5.12)$$

Assuming  $\theta/r \neq 1$ , the quadratic expression can be solved for,

$$p_x^* = \frac{a(3 \pm \sqrt{1 + 8(\frac{\theta}{r})})}{4(1 - \frac{\theta}{r})}, \text{ where } p_m > p_x^* > 0 \quad (7.5.13)$$

From equation (7.5.13) it is evident that the maximum solution for  $p_x^*$  fails to lie within the required bounds for the optimal price. When  $\theta/r > 1$ , the maximum solution is less than zero, while when  $\theta/r < 1$ , the maximum solution is greater than the unregulated monopoly price. Consequently, the solution here is given by,

$$p_x^* = \frac{a(3 - \sqrt{1 + 8(\frac{\theta}{r})})}{4(1 - \frac{\theta}{r})}, \text{ when } \frac{\theta}{r} \neq 1$$

If  $\theta/r = 1$ , then the quadratic expression in equation (7.5.12) can be solved for the optimal linear access price,

$$p_x^* = \frac{a}{3}, \text{ when } \frac{\theta}{r} = 1$$

Therefore, where the regulator only controls the linear price the monopoly investor charges, the regulated access price that maximises the net present value to society is,

$$p_x^*(\frac{\theta}{r}) = \begin{cases} \frac{a(3 - \sqrt{1 + 8(\frac{\theta}{r})})}{4(1 - \frac{\theta}{r})}, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{a}{3}, & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.14)$$

To confirm  $dp_x^*/d(\frac{\theta}{r}) < 0$  when  $\theta/r \neq 1$ , the derivative of equation (7.5.14) is taken.

$$\frac{dp_x^*}{d(\frac{\theta}{r})} = \frac{a[-5 - 4(\frac{\theta}{r}) + 3\sqrt{1 + 8(\frac{\theta}{r})}]}{4\sqrt{1 + 8(\frac{\theta}{r})}(\frac{\theta}{r} - 1)^2} \quad (7.5.15)$$

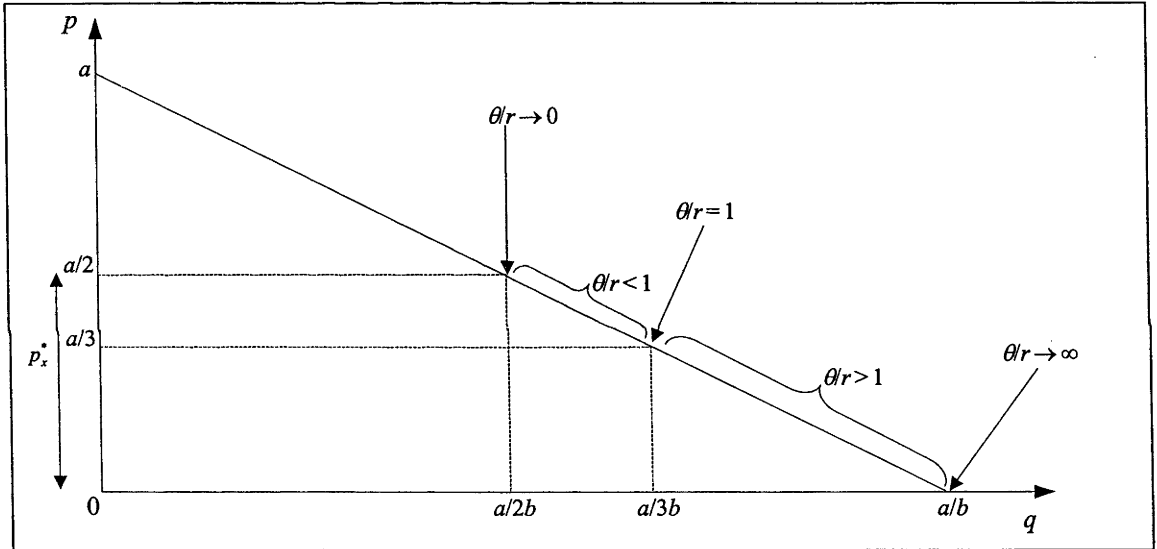


For  $dp_x^*/d(\frac{\theta}{r}) < 0$ , the expression in the numerator of (7.5.15) must be less than zero, i.e.,  $-5 - 4(\frac{\theta}{r}) + 3\sqrt{1 + 8(\frac{\theta}{r})} < 0$ . As this simplifies to the requirement that  $16(\frac{\theta}{r} - 1)^2 > 0$ , it implies that  $dp_x^*/d(\frac{\theta}{r}) < 0$ , and the optimal regulated price  $p_x^*$  is:

$$p_x^*(\frac{\theta}{r}) = \begin{cases} > \frac{a}{3}, & \text{when } \frac{\theta}{r} < 1 \\ \frac{a}{3}, & \text{when } \frac{\theta}{r} = 1 \\ < \frac{a}{3}, & \text{when } \frac{\theta}{r} > 1 \end{cases} \quad (7.5.16)$$

This outcome is captured in the price-quantity space diagram of Figure 7.5.1.

**FIGURE 7.5.1 THE OPTIMAL PRICE FOR A MONOPOLY INVESTOR**



Evaluating consumer surplus and revenue at  $p_x^*$  and substituting the outcomes (given by Appendix A.7.5) into the expressions in Table 6.3.1, yields

$$t_w(p_x^*) = \begin{cases} \frac{1}{\theta} \log \left( \frac{16br(1 + \frac{\theta}{r})(\frac{\theta}{r} - 1)^2 C_0}{a^2(3 - 20(\frac{\theta}{r}) + 8(\frac{\theta}{r})^2 + 3\sqrt{1 + 8(\frac{\theta}{r})})} \right), & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \log \left( \frac{9brC_0}{2a^2} \right), & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.17)$$

$$t_x(p_x^*) = \begin{cases} \frac{1}{\theta} \log \left( \frac{16br(1 + \frac{\theta}{r})(1 - \frac{\theta}{r})^2 C_0}{a^2(3 - \sqrt{1 + 8(\frac{\theta}{r})})(1 - 4(\frac{\theta}{r}) + \sqrt{1 + 8(\frac{\theta}{r})})} \right), & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \log \left( \frac{9brC_0}{a^2} \right), & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.18)$$

$$NPV_f^*(p_x^*) = \begin{cases} 16^{-\frac{r}{\theta}-1} \left(\frac{\theta}{r}\right) C_0 \left( \frac{a^2 \left(3 - \sqrt{1+8\left(\frac{\theta}{r}\right)}\right) \left(1 - 4\left(\frac{\theta}{r}\right) + \sqrt{1+8\left(\frac{\theta}{r}\right)}\right)}{brC_0 \left(\frac{\theta}{r} - 1\right)^2 \left(1 + \frac{\theta}{r}\right)} \right)^{1+\frac{r}{\theta}}, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \left(\frac{a^2}{9b}\right) \left(\frac{a^2}{9brC_0}\right), & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.19)$$

$$NPV_s^*(p_x^*) = \begin{cases} \frac{1}{r} \left( \frac{a^2 \left[4 - 8\left(\frac{\theta}{r}\right) + \frac{r}{\theta} \left(1 + \sqrt{1+8\left(\frac{\theta}{r}\right)}\right)\right]}{16b \left(1 - \frac{\theta}{r}\right) \left(1 + \frac{r}{\theta}\right)} \right) \left( \frac{a^2 \left(3 - \sqrt{1+8\left(\frac{\theta}{r}\right)}\right) \left(1 - 4\left(\frac{\theta}{r}\right) + \sqrt{1+8\left(\frac{\theta}{r}\right)}\right)}{16brC_0 \left(1 - \frac{\theta}{r}\right)^2 \left(1 + \frac{\theta}{r}\right)} \right)^{\frac{r}{\theta}}, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \left(\frac{a^2}{3b}\right) \left(\frac{a^2}{9brC_0}\right), & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.20)$$

#### 7.5.4 Price Regulation of the Competitive Investor/Price and ROR Regulation of the Monopoly Investor

The analysis in Section 7.4 illustrates that for both a competitive investor and ROR-regulated monopoly investor, the optimal regulated price must satisfy,

$$-\frac{CS(p_o^*)}{\pi(p_o^*)} \cdot \frac{\pi'(p_o^*)}{CS'(p_o^*)} = \frac{\theta}{r}$$

The working in Appendix A.7.6 shows that, by evaluating consumer surplus, revenue and its derivatives at price  $p_o^*$ , and substituting into the optimal condition,

$$p_o^*\left(\frac{\theta}{r}\right) = \frac{a}{2\left(1 + \frac{\theta}{r}\right)} \quad (7.5.21)$$

Where the rate of technological progress is equal to the rate of return (i.e.  $\theta/r = 1$ ), the optimal regulated price in equation (7.5.21) is,

$$p_o^* = \frac{a}{2(1+1)} = \frac{a}{4} \quad (7.5.22)$$

Thus, the optimal price for a competitive or ROR-regulated monopoly investor is,

$$p_o^*\left(\frac{\theta}{r}\right) = \begin{cases} \frac{a}{2\left(1 + \frac{\theta}{r}\right)}, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{a}{4}, & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.23)$$

As the derivative of equation (7.5.23) is,

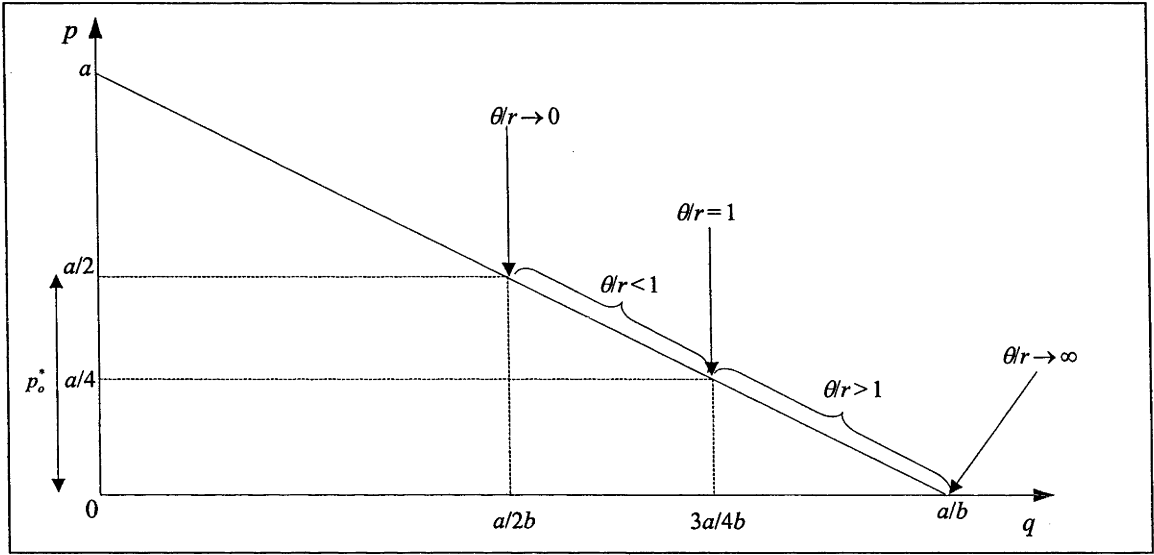
$$\frac{dp_o^*}{d\left(\frac{\theta}{r}\right)} = \frac{-a}{2\left(\frac{\theta}{r} + 1\right)^2} < 0$$

the optimal price  $p_o^*$  will be,

$$p_o^*\left(\frac{\theta}{r}\right) = \begin{cases} > \frac{a}{4}, & \text{when } \frac{\theta}{r} < 1 \\ = \frac{a}{4}, & \text{when } \frac{\theta}{r} = 1 \\ < \frac{a}{4}, & \text{when } \frac{\theta}{r} > 1 \end{cases} \quad (7.5.24)$$

The result is highlighted in Figure 7.5.2.

**FIGURE 7.5.2 THE OPTIMAL PRICE FOR A COMPETITIVE INVESTOR**



Using equation (6.4.3), the price  $p_d^*$  that induces the competitive or ROR-regulated monopoly investor to provide the investment at the dynamically-efficient time here is,

$$p_d^*\left(\frac{\theta}{r}\right) = \frac{a}{1 + 2\left(\frac{\theta}{r}\right)} \quad (7.5.25)$$

The result confirms that the optimal linear price  $p_o^*$  is dynamically inefficient and a type of second-best efficient price. As by assumption  $a/2 \geq p \geq 0$ , the result also shows that dynamic efficiency is not possible here if  $\theta/r < 1/2$ .

Substituting  $p_o^*$  into consumer surplus and revenue flow, gives the outcomes outlined in the Appendix in A.7.7. Using these expressions and the outcomes from Table 6.3.1,

$$t_w(p_o^*) = \begin{cases} \frac{1}{\theta} \log \left( \frac{8brC_0 \left(1 + \frac{\theta}{r}\right)^3}{a^2 \left(3 + 8\left(\frac{\theta}{r}\right) + 4\left(\frac{\theta}{r}\right)^2\right)} \right), & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \log \left( \frac{64brC_0}{15a^2} \right), & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.26)$$

$$t_o(p_o^*) = \begin{cases} \frac{1}{\theta} \log \left[ \frac{4brC_0 \left(1 + \frac{\theta}{r}\right)^2}{a^2 \left(1 + 2\left(\frac{\theta}{r}\right)\right)} \right], & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \log \left[ \frac{16brC_0}{3a^2} \right] & , \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.27)$$

$$NPV_s^o(p_o^*) = \begin{cases} \frac{1}{r} \left( (2\theta + r) C_0 \right) \left( \frac{1}{2} \right)^{3 + \frac{2r}{\theta}} \left( \frac{a^2 (2\theta + r)}{b(\theta + r)^2 C_0} \right)^{1 + \frac{r}{\theta}}, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{1}{r} \left( \frac{9a^2}{32b} \right) \left( \frac{3a^2}{16brC_0} \right) & , \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (7.5.28)$$

From inspection of the above equations, it is difficult to compare investment timing and the net present values to society when  $\theta/r \neq 1$ . Hence, Section 7.5.5 uses a numerical example to compare investment timing and the net present value to society under the various regimes using different values of  $\theta/r$ .

### 7.5.5 Comparing the Schemes using Numerical Examples

To compare access prices, investment timing, and the net present value to society using a numerical example, the following values are assigned to each of the parameters:<sup>15</sup>

- for the linear demand curve,  $a = 10$  and  $b = 0.01$ ;
- the cost of capital investment at time 0 is  $C_0 = 1\,000\,000$ ; and
- the constant risk-free interest rate is  $r = 0.05$ ; and
- the rate of technological progress can be  $\theta = 0.01, 0.025, 0.05$  or  $0.10$ .

#### 7.5.5.1 Comparing the Access Prices

The outcomes for the respective access prices under the different regime are outlined in Table 7.5.1. To remind readers of the notation used in Table 7.5.1:

- $A_x^*, p^* = 0$  is the socially-optimal tariff for the monopoly investor;
- $A_o^*, p^* = 0$  is the socially-optimal tariff for the competitive or ROR-regulated monopoly investor;
- $p_m$  is the unregulated monopoly price;
- $p_x^*$  is optimal linear price for a monopoly earning the rate of return  $\theta + r$ ;

<sup>15</sup> Other values were also adopted for  $a, b, C_0$  and  $r$ , and similar basic results were established to those outlined in this Section.

- $p_d^*$  is the price that induces investment at the dynamically-efficient time; and
- $p_o^*$  is the optimal linear price for a competitive or ROR-regulated monopoly.

**TABLE 7.5.1 THE PRICE FOR ACCESS**

$\theta r$ ( $p, A$ )	1/5	1/2	1	2
$A_x^*, p^*=0$	5000			
$A_o^*, p^*=0$	4166.67	3333.33	2500	1666.67
$p_m$	5			
$p_x^*$	4.34	3.82	3.33	2.81
$p_o^*$		5	3.33	2
$p_o^*$	4.17	3.33	2.5	1.67

The results in the table confirm that:

- as shown in equation (6.6.10), the fixed fee in the socially-optimal two-part tariff for a competitive or ROR-regulated monopoly investor will be lower, the higher the rate of technological progress is. For example, when  $\theta = 0.025$ , the optimal fixed fee for the competitive or ROR-regulated monopoly investor is 3333.33, while when  $\theta = 0.05$ , the optimal fixed fee is only 2500;
- the optimal linear price for the monopoly and competitive (or ROR-regulated monopoly) investor —  $p_x^*$  and  $p_o^*$  — will be lower, the higher the rate technological progress is. For example, when  $\theta = 0.01$ , the optimal linear price for the monopoly investor is 4.34, and the optimal linear price for the competitive investor is 4.17. However, when  $\theta = 0.10$ , the optimal linear price for the monopoly investor is only 2.81, while the optimal linear price for the competitive investor is 1.67; and
- the optimal linear price  $p_o^*$  is not equal to the price that the induces the competitive or ROR-regulated monopoly investor to undertake the investment at the dynamically-efficient time,  $p_d^*$ . Table 7.5.1 indicates that when  $\theta = 0.05$ , the optimal linear price  $p_o^*$  is 2.5, while the dynamically-efficient price is 3.3.

7.5.5.2 Comparing Investment Timing

Table 7.5.2 illustrates the outcomes for the socially-optimal investment time, and the investment timing by a monopoly and competitive (or ROR-regulated monopoly) investor. The table adopts the notation used throughout the Chapter 6 and 7, that is:

- $t_w(p)$  denotes the socially-optimal investment time at any given usage price  $p$ ;
- $t_x(p)$  denotes the investment timing by the monopoly investor at any given usage price  $p$ ; and
- $t_o(p)$  denotes the investment timing by the competitive or ROR-regulated monopoly investor at any given usage price  $p$ .

TABLE 7.5.2 DYNAMICALLY-EFFICIENT, COMPETITIVE AND MONOPOLY INVESTMENT TIMING

$\theta r$ $t_w(p)$	1/5	1/2	1	2
$t_w(p^* = 0)$	248.49	108.32	59.92	34.01
$t_w(p_m)$	277.26	119.83	65.67	36.89
$t_w(p_x^*)$	269.32	114.63	62.27	34.83
$t_w(p_o^*)$	267.52	113.03	61.21	34.29
$\theta r$ $t_x(p)$	1/5	1/2	1	2
$t_x(p_m)$	317.81	136.05	73.78	40.94
$t_x(p_x^*)$	319.58	138.34	76.13	43.08
$\theta r$ $t_o(p)$	1/5	1/2	1	2
$t_o(p_m)$	299.57	119.83	59.92	29.92
$t_o(p_o^*)$	302.39	124.54	65.67	35.84

The results in the table confirm that:

- the lower the usage price, the earlier is the dynamically-efficient time  $t_w$ . The lowest usage price of  $p = 0$ , yields the earliest dynamically-efficient time for any value of  $\theta$ , while the highest possible usage price here  $p_m$ , yields the latest dynamically-efficient time for any value of  $\theta$ ,
- for any given usage price  $p$ , the monopoly invests at a time  $t_x$  that is after the investment timing by the competitive investor  $t_o$ , and the socially-optimal time  $t_w$ ;
- the unregulated competitive and ROR-regulated monopoly investor may undertake the investment before, after or at the socially-optimal time  $t_w$ . For example:
  - if  $\theta = 0.01$ , the unregulated competitive and ROR-regulated monopoly investor inefficiently delays the investment;
  - if  $\theta = 0.25$ , the unregulated competitive and ROR-regulated monopoly investor provides the infrastructure at the socially-optimal time 119.83; and
  - if  $\theta = 0.5$ , the unregulated competitive and ROR-regulated monopoly investor invests prematurely.

These outcomes also indicate that with a higher rate of technological progress  $\theta$ , it is more likely the condition  $CS(p_m)/\pi(p_m) < \theta/r$  is met, and that the competitive investor provides the essential infrastructure too early; and

- at the socially-optimal price, the competitive or ROR-regulated monopoly investor is dynamically inefficient. For example, when  $\theta = 0.1$ , the dynamically-efficient time is at 34.29, while the firm invests at time 35.84.

### 7.5.5.3 Comparing the Net Present Value to Society

Assuming the value of the rate of technological progress lies between  $0 < \theta < 0.1$ , the respective net present values to society achieved under each regime, can be graphed and compared as a function of  $\theta$ . This is shown in Figure 7.5.3. In this diagram and the table below, the following notation is once again used to denote the respective net present values to society achieved at the various prices is:

- $NPV_s^w(p^* = 0)$  is the socially-optimal net present value to society;
- $NPV_s^x(p)$  is the net present value to society achieved by the monopoly investor at any given usage price  $p$ ; and
- $NPV_s^o(p)$  is the net present value to society achieved by the competitive or ROR-regulated investor at any given usage price  $p$ .

FIGURE 7.5.3 COMPARING THE NET PRESENT VALUE TO SOCIETY

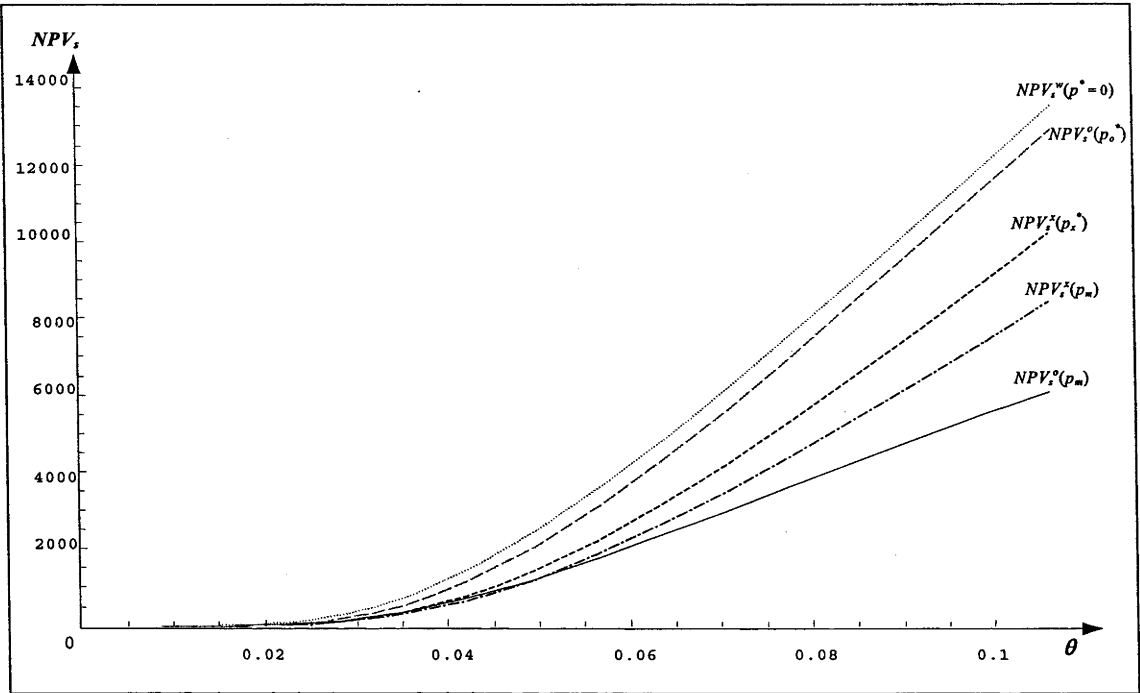


Figure 7.5.3 illustrates that as anticipated from the analysis in Section 7.4, aside from the socially-optimal two-part access tariff, price regulation of the competitive or ROR-regulated monopoly investor yields the highest net present value to society for all relevant values of  $\theta$ . Further, the diagram highlights that price regulation is better for society than no regulation of the monopoly investor and that the competitive or ROR-regulated monopoly investor is likely to yield worse outcomes for society the higher the rate of technological progress is. These results are summarised in Table 7.5.3 below, by calculating the net present value to society where  $\theta = 0.01, 0.025, 0.05$  and  $0.10$ .

TABLE 7.5.3 THE NET PRESENT VALUE TO SOCIETY UNDER EACH SCHEME

$\theta r$ $NPV_s^*$	1/5	1/2	1	2
$NPV_s^w(p^* = 0)$	0.0670	148.15	2500	12171.61
$NPV_s^x(p_m)$	0.0042	46.30	1250	7530.80
$NPV_s^o(p_m)$	0.0078	62.50	1250	5590.17
$NPV_s^x(p_x^*)$	0.0046	53.43	1481.48	9126.12
$NPV_s^o(p_o^*)$	0.0092	87.79	2109.38	11574.07



The above results highlight a number of important points:

- where only one firm can undertake the investment, or one firm has a significant cost advantage over its rival, and there is a linear price for access, a combination of price and ROR regulation can be optimal. This suggests there may be some benefit from “hybrid” regulation;
- where there is the potential for competition to arise providing the essential infrastructure, a better outcome for society is achieved by allowing competition to construct the linear price-regulated investment, rather than auctioning off the right; and
- the higher the rate of technological progress is, all other things being equal, the greater the net present value to society that is achieved from the investment. However, rather than setting a higher linear price or allowing an access holiday, in order to maximise the benefit to society, the analysis here suggests that the regulator should set a lower access price.

## 7.6 Forward-Looking Cost Regulation of A Monopoly Investor

In the analysis in Section 6.5 and 7.4, the allowed fair rate of return was based on historical or backward-looking (BL) cost of the investment. However, as Chapter 4 outlines, a great deal of access-pricing regulation today is based on forward-looking (FL) cost regulation. This Section examines the impact that FL cost regulation has upon the investment timing and net present value to society, when the investor charges a linear price for access.

As in Chapter 5, it is illustrated that under FL cost regulation, the firm must be allowed to earn the higher rate of return on the investment  $\theta + r$ , and that the access price will be decreasing over time. Employing a linear demand curve for access, it is found that the FL cost-regulated monopoly investor invests later than a BL cost ROR-regulated monopoly investor subject to the optimal access price  $p_o^*$ . To induce the earliest possible investment it appears the regulator must allow the firm to initially charge the unregulated monopoly price  $p_m$ . The result however does not suggest that there is a case for an access holiday here, as the access charge is required to immediately decrease after the investment has been made. Finally, using the parameter values from the numerical example in Section 7.5, it is found that FL cost regulation of the monopoly investor leads to a lower net present value to society than the optimal combination of price and ROR regulation on the BL costs of the firm. This outcome appears consistent with results established in Chapter 5. It indicates that once again the higher benefit to society under BL cost regulation identified by GSW (2001), arises even in the absence of the uncertainty that was central to their analysis.

### 7.6.1 The Allowed Fair Rate under FL Cost Regulation

It is assumed initially that the firm subject to FL cost regulation, undertakes the investment at some given time  $\tau$  where it charges an access price  $p_\tau$ , and earns revenue of  $\pi(p_\tau)$ . As the revenue the firm is allowed to earn at each instant after the investment has been made decreases over time at the same rate as the cost-decreasing rate of technological progress  $\theta$ ,

$$\pi(p_t) = \pi(p_\tau) e^{-\theta(t-\tau)}, \forall t \geq \tau \quad (7.6.1)$$

As in Section 5.2 of Chapter 5, in order for the investor to recover costs it must be allowed to earn the fair rate  $f_{FL} = \theta + r$ . That is, under FL costs, the minimum rate of

return required for the investment in infrastructure to be undertaken, must compensate the firm not only for the normal rate of return on capital  $r$ , but also the capital loss  $\theta$  associated with the method used by the regulator to value the asset. To see this, it is assumed that upon investing at time  $\tau$ , the firm subject to FL cost regulation, earns

$$\pi(p_t) = f_{FL} C_0 e^{-\theta(t-\tau)}, \forall t \geq \tau \quad (7.6.2)$$

This implies that the net present value derived by the firm that charges the decreasing price over time  $p_t$ , will be,

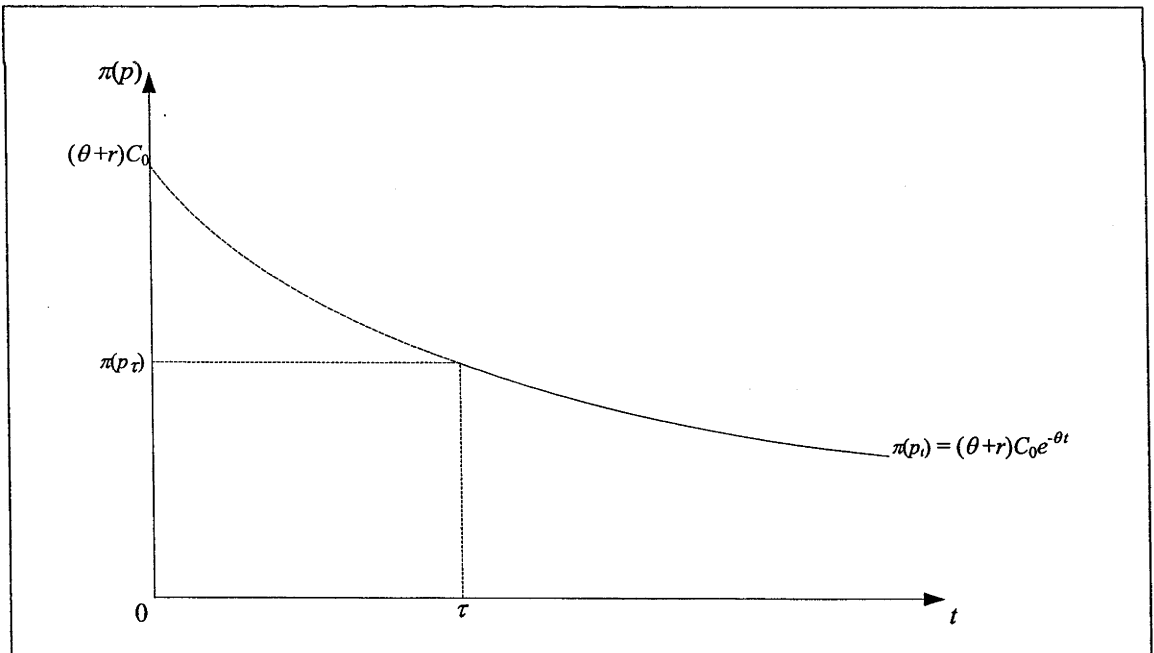
$$NPV_f(p_t) = \int_{\tau}^{\infty} f_{FL} C_0 e^{-(\theta+r)t} dt - C_0 e^{-(\theta+r)\tau} \quad (7.6.3)$$

Setting equation (7.6.3) equal to zero and solving for  $f_{FL}$ , yields

$$f_{FL} = \theta + r \quad (7.6.4)$$

The path followed by the decreasing net cash flow in each period after the investment has occurred at time  $\tau$  is mapped below in Figure 7.6.1.

**FIGURE 7.6.1 THE NET CASH FLOW PATH UNDER FL COST REGULATION**



## 7.6.2 Investment Timing under FL Cost Regulation

It is assumed here that the FL cost-regulated firm invests at the same time as the BL cost ROR-regulated monopoly investor subject to price regulation. This assumption is made to assess whether there exists an initial linear access price under FL cost regulation that will allow the firm to invest at the same time as the BL cost-regulated

firm. If such a price does not exist, then it will imply the original assumption that both types of regulation induce the firm to invest at time  $t_o(p_o^*)$  is incorrect. As the firm subject to FL cost regulation has a price that decreases over time with the allowed revenue, to avoid any confusion, the investment time of  $t_o(p_o^*)$  is just denoted here by  $t^*$ .

As illustrated in Section 7.4,  $t^*$  is the investment time associated with the linear price, which maximises the net present value to society achieved by a BL cost-based-ROR-regulated monopoly investor. At this time, the firm earns revenue of,

$$\pi(p_o^*) = rC_{t^*} = rC_0 e^{-\theta t^*} \quad (7.6.5a)$$

As the firm facing FL cost regulation is allowed to earn the rate of return  $\theta + r$ , the revenue stream from investing at the same given time  $t^*$  is,

$$\pi(p_{t^*}) = (\theta + r)C_{t^*} = (\theta + r)C_0 e^{-\theta t^*} \quad (7.6.5b)$$

Although price  $p_o^*$  is known, the initial price  $p_{t^*}$  charged by the firm facing FL cost regulation for the investment undertaken at time  $t^*$ , is not known. To derive this linear access price, equation (7.6.5b) is manipulated as follows,

$$\pi(p_{t^*}) = \frac{(\theta + r)}{r} rC_{t^*}$$

By then substituting in equation (7.6.5a), a relationship is established between the net cash flow under each type of regulation at time  $t^*$ .

$$\pi(p_{t^*}) = \frac{(\theta + r)}{r} \pi(p_o^*)$$

Using the linear demand curve and substituting in equation (7.5.23) for price  $p_o^*$ , the following quadratic expression for  $p_{t^*}$  is derived,

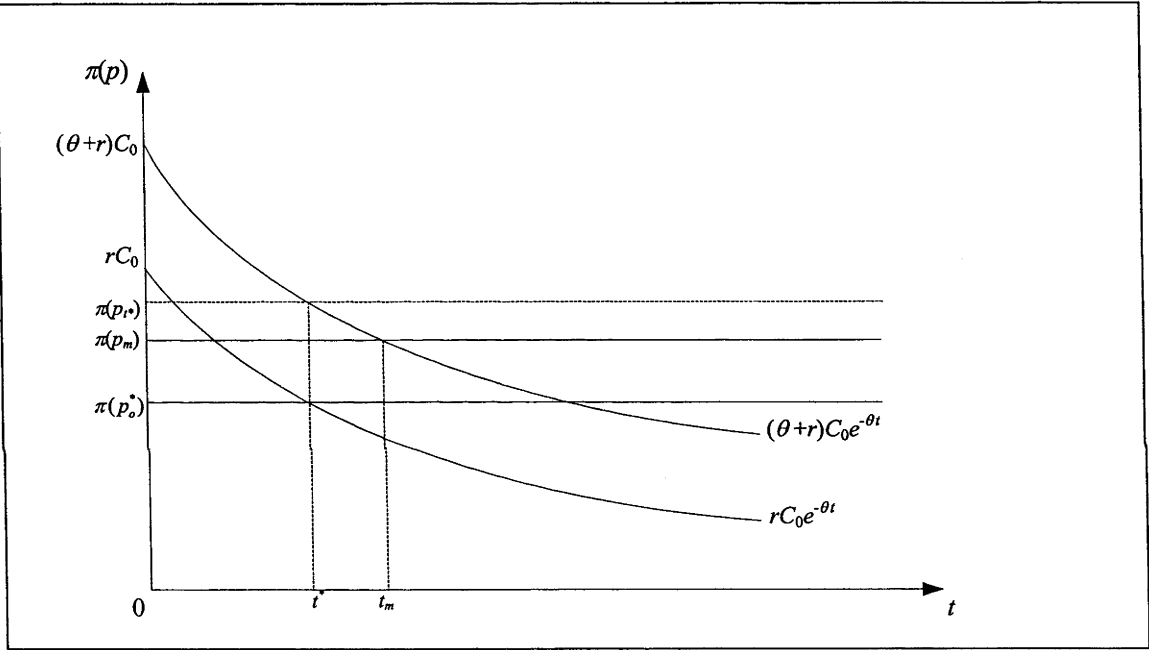
$$p_{t^*}^2 - ap_{t^*} + \frac{a^2(1 + 2(\frac{\theta}{r}))}{4(1 + \frac{\theta}{r})} = 0$$

Solving this, the initial price needed to induce the firm facing FL costs to invest at the same time  $t^*$  is,

$$p_{t^*} = \frac{a(1 + \frac{\theta}{r}) \pm \sqrt{-a^2(\frac{\theta}{r})(1 + a)}}{2(1 + \frac{\theta}{r})}$$

However as,  $-a^2 \left(\frac{\theta}{r}\right)(1+a) < 0$ , all solutions for  $p_{t^*}$  will be imaginary. As price must be a real number, the result implies that the initial assumption of identical timing is incorrect, and no initial access price under FL cost regulation exists that allows the firm to recover the cost of the investment at time  $t^*$ . Therefore, the revenues required for investment at time  $t^* - \pi(p_{t^*})$  — exceed the maximum possible net cash flow  $\pi(p_m)$  that can be earned with a linear price. This suggests that the investment timing under FL costs will occur later than the investment timing of a competitive or BL cost-based-ROR-regulated monopoly subject to optimal linear price regulation.

**FIGURE 7.6.2 INVESTMENT TIMING UNDER FL COST REGULATION**



To resolve the issue of when a firm subject to FL cost regulation will invest, it is assumed here that the regulator allows the investor to earn the rate of return  $(\theta + r + \varepsilon)$ . As this return provides the firm with some economic rent, in order to maximise the net present value it receives, the firm has an incentive to invest at the earliest possible time. This involves charging the unregulated monopoly price  $p_m$ , earning a net cash flow of  $\pi(p_m)$ , and investing at the given time  $\tau$ , where the following condition is satisfied,

$$(\theta + r + \varepsilon) = \frac{\pi(p_m)}{C_0 e^{-\theta \tau}}$$

Rearranging this expression, it implies that the investment occurs at time,

$$\tau = \frac{1}{\theta} \log \left( \frac{(\theta + r + \varepsilon) C_0}{\pi(p_m)} \right)$$

Assuming that  $\varepsilon \rightarrow 0$ , the investor facing FL cost regulation invests at exactly the same time as the unregulated monopoly investor in Section 6.6. That is,

$$\tau = t_x(p_m) = \frac{1}{\theta} \log \left( \frac{(\theta + r)C_0}{\pi(p_m)} \right) \quad (7.6.6)$$

To simplify the notation for the remainder of the analysis in this Section, the investment time  $t_x(p_m)$  is denoted by the term  $t_m$ .

As the regulator aims to generate the flow of social surplus at the earliest possible time under FL cost regulation, the unregulated linear access price  $p_m$  also represents the initial price that the regulator will allow the firm to charge. However, this result does not indicate there is support for an access holiday. In this framework, once the investment has been made at time  $t_m$ , the regulator requires the price to immediately decrease from its initial level  $p_m$ .<sup>16</sup> The investment timing of the firm under FL cost regulation is shown in Figure 7.5.2.

### 7.6.3 The Net Present Value to Society under FL cost Regulation

Section 5.4 of Chapter 5 established that for an existing investment, a constant BL cost-based price leads to a higher net present value to society than a FL cost-based price, which decreases over time. As in this framework with linear demand, FL cost regulation also induces later investment timing, it should follow that BL cost regulation still provides greater benefits to society. To confirm this outcome an expression for the net present value to society under FL costs is derived, and a numerical example used to compare the two types of cost regulation.

As the present value of the revenues to the firm is equal to the present value of the costs of the investment, the net present value to society under FL cost regulation is equal to the present value of the stream of consumer surplus. The problem here is that, whilst it is known how revenue evolves over time once the investment occurs, it is not immediately obvious from this how the consumer surplus at each instant changes over time. To derive the expression for the net present value to society from the investment, the price and consumer surplus must be found at some arbitrary time  $t > t_m$ .

At some time  $t$ , the firm facing FL cost-based regulation will earn the net cash flow,

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<sup>16</sup> For a model where there is the need for an access holiday to induce earlier investment, see Gans and King (2002). They consider a world of uncertainty, where the truncation problem arises.

$$\pi(p_t) = \pi(p_m)e^{-\theta(t-t_m)}, \text{ where } t > t_m \quad (7.6.7)$$

Using the linear demand curve from Section 7.5, i.e.  $q(p) = (a - p)/b$ , equation (7.6.7) is simplified in Section A.7.8 of the Appendix, to give a quadratic expression in price  $p_t$ ,

$$p_t^2 - ap_t + \frac{a^2}{4}e^{-\theta(t-t_m)} = 0 \quad (7.6.8)$$

Solving this in Section A.7.9 of the Appendix yields,

$$p_t = \frac{a}{2} \left[ 1 \pm \sqrt{1 - e^{-\theta(t-t_m)}} \right] \quad (7.6.9)$$

As the allowed price at time  $t$  must be less than the initial monopoly price  $a/2$ , the only solution for  $p_t$  in equation (7.6.9) is the minimum solution,

$$p_t = \frac{a}{2} \left[ 1 - \sqrt{1 - e^{-\theta(t-t_m)}} \right] \quad (7.6.10)$$

Given this expression for price, the consumer surplus at time  $t$  is,

$$CS(p_t) = \frac{(a - p_t)^2}{2b} = \frac{a^2}{8b} \left[ 1 + \sqrt{1 - e^{-\theta(t-t_m)}} \right]^2 \quad (7.6.11)$$

and net present value to society is then,

$$NPV_s(p_t) = \frac{a^2}{8b} \int_{t_m}^{\infty} \left[ 1 + \sqrt{1 - e^{-\theta(\tau-t_m)}} \right]^2 e^{-r\tau} d\tau$$

Solving this yields,<sup>17</sup>

$$NPV_s(p_t) = \frac{a^2}{8b} \left[ e^{-rt_m} \left( \frac{2}{r} - \frac{1}{\theta + r} + \frac{\Gamma(\frac{r}{\theta})\sqrt{\pi}}{\Gamma(\frac{3}{2} + \frac{r}{\theta})\theta} \right) \right] \quad (7.6.12)$$

$$\text{where, } \pi \cong 3.14159, \Gamma\left(\frac{r}{\theta}\right) = \int_0^{\infty} \tau^{\frac{r}{\theta}-1} e^{-\tau} d\tau \text{ and } \Gamma\left(\frac{3}{2} + \frac{r}{\theta}\right) = \int_0^{\infty} \tau^{\left(\frac{3}{2} + \frac{r}{\theta}\right)-1} e^{-\tau} d\tau$$

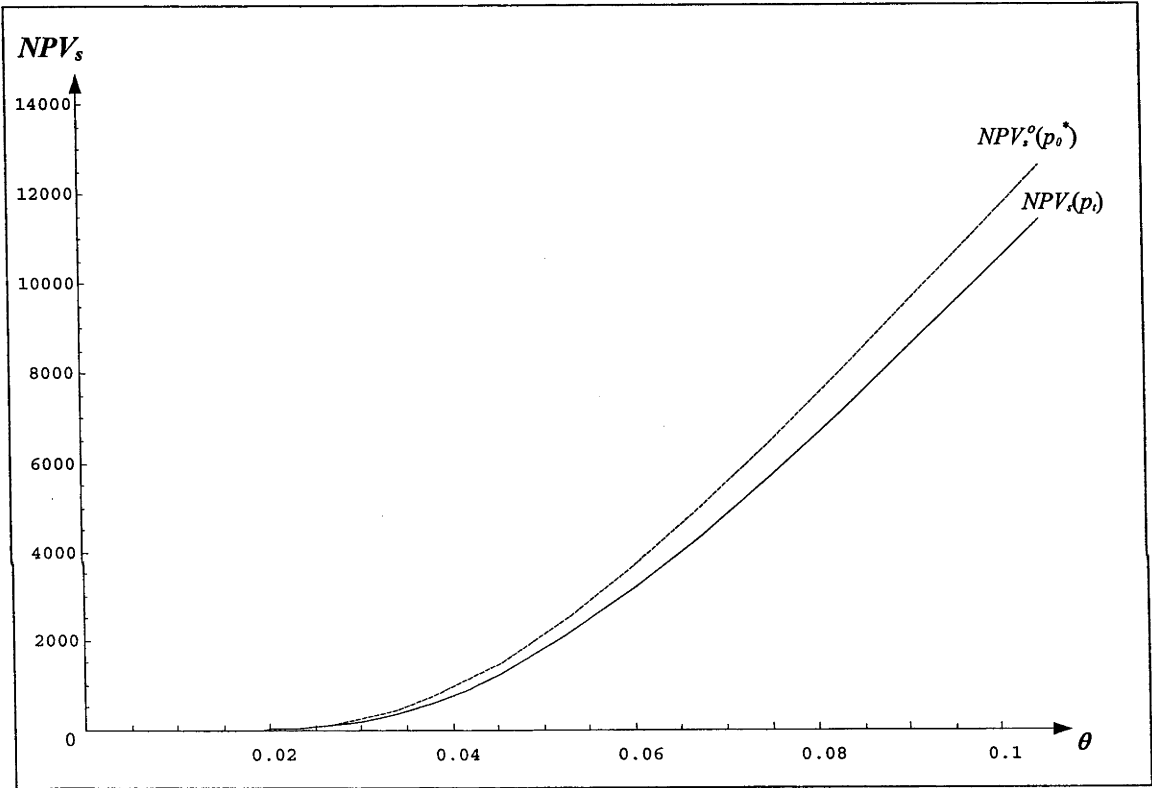
Substituting the expression for  $t_m$  into equation (7.6.12),

$$NPV_s(p_t) = \frac{a^2}{8b} \left[ \left( \frac{1}{4} \right)^{\frac{r}{\theta}} \left( \frac{a^2}{b(\theta + r)C_0} \right)^{\frac{r}{\theta}} \left( \frac{2}{r} - \frac{1}{\theta + r} + \frac{\Gamma(\frac{r}{\theta})\sqrt{\pi}}{\Gamma(\frac{3}{2} + \frac{r}{\theta})\theta} \right) \right] \quad (7.6.13)$$

<sup>17</sup> This outcome was derived with the assistance of the software package Mathematica Version 4.1.

A numerical example that compares this net present value, with that achieved by a BL cost-based-ROR-regulated monopoly subject to optimal linear price regulation, is done by adopting the parameters values of Section 7.5 — i.e.  $a = 10$ ,  $b = 0.01$ ,  $C_0 = 1\,000\,000$  and  $r = 0.05$ .<sup>18</sup> From this, a graph is drawn that depicts the net present values to society under BL cost (i.e.  $NPV_s^o(p_o^*)$ ) and FL cost (i.e.  $NPV_s(p_t)$ ) regulation as a function of  $\theta$ , where  $0 < \theta < 0.1$ .

**FIGURE 7.6.3 NET PRESENT VALUE TO SOCIETY UNDER BL AND FL COSTS**



From the diagram in Figure 7.6.3, as anticipated, the net present value to society using a combination of price and ROR regulation of BL costs, will exceed the net present value to society achieved under FL cost regulation for all the relevant values of  $\theta$ .

The outcome in the diagram are summarised in Table 7.6.1. This shows the net present values to society under both schemes using the given parameter values for  $a$ ,  $b$ ,  $r$  and  $C_0$ , and the values for  $\theta$  of 0.01, 0.025, 0.05 and 0.1.

<sup>18</sup> Similar basic results were found to hold when other values were adopted for  $a$ ,  $b$ ,  $r$  and  $C_0$ .



**TABLE 7.6.1 THE NET PRESENT VALUE TO SOCIETY UNDER BL AND FL COSTS**

$\theta/r$ $NPV_s^*$	1/5	1/2	1	2
$NPV_s^*(p_o)$	0.0092	87.79	2109.38	11574.07
$NPV_s(p_i)$	0.0060	66.67	1770.83	10448.90

To confirm the outcome that FL cost regulation leads to later investment than BL cost regulation, numerical results for investment timing are also provided in Table 7.6.2.

**TABLE 7.6.2 INVESTMENT TIMING UNDER BL AND FL COSTS**

$\theta/r$ $t(p)$	1/5	1/2	1	2
$t_s(p_o)$	302.39	124.54	65.67	35.84
$t_s(p_m)$	317.81	136.05	73.78	40.94

With decreasing costs over time, the results here indicate that, FL cost regulation of the monopoly investor induces later investment, and a lower net present value to society, than BL cost regulation. This reinforces the idea from Chapter 5 that the key conclusions of GSW (2001) may arise without the uncertainty that was central to their analysis. The addition of the stochastic costs used in the GSW model is only likely to exacerbate the advantage of BL cost regulation to society identified here. The reason for this is that cost uncertainty leads to the fixed net cash flow in each period under BL cost regulation, being compared with the uncertain net cash flows earned in each period under FL cost regulation. As the concave net cash flow function of the firm effectively acts in the same manner as a utility function for a risk-averse investor, the additional uncertainty associated with FL costs makes the regime even less desirable to the firm and society than it was before.

## 7.7 Conclusion

Using the framework established in Section 6.2, and setting the fixed fee for access  $A$  equal to zero, this Chapter examined the outcome for society when investors charged a linear price for access. In particular, it looked at the optimal linear price that should be charged, given that the allocatively-efficient-short-run-marginal-cost-based price failed to adequately compensate the investor.

In this Chapter it was established that:

- when the linear price is left unregulated, the monopoly and competitive (or ROR-regulated monopoly) investor each charge the unregulated monopoly price  $p_m$  and generate the same level of allocative efficiency. From the outcomes in Chapter 6, the monopoly investor is more likely to be dynamically efficient and induce greater benefit to society, with a higher rate of cost-decreasing technological progress;
- society benefits from the introduction of a small degree of linear price regulation upon the investor;
- the optimal linear access prices derived for the monopoly and competitive (or ROR-regulated monopoly) investor, are allocatively and dynamically inefficient. This implies that, given price must be set above the allocatively-efficient-short-run marginal cost, the optimal way to do this is **not** to set a price that is dynamically efficient. This idea that an efficient outcome does not maximise welfare given an existing distortion, is similar to the idea in the theory of second best;
- as the optimal linear access price for the competitive or ROR-regulated monopoly investor is above the allocatively-efficient-short-run marginal cost, yet below the monopoly price, it has similar properties to the price derived by EQZ (2003);
- the optimal linear price the regulator should set for each investor is decreasing in the rate of technological progress. In terms of public policy, this suggests that even without the standard concerns about downstream market competition or future investment in infrastructure, there is less of a case for an access holiday — i.e. no regulation — where there is a higher rate of technological progress experienced in an industry;
- anticipatory retardation may not necessarily be detrimental for society;
- price and ROR regulation have different effects in the model. In an industry experiencing rapid technological progress, ROR regulation simulates the effect of

competition to construct the investment — i.e. competition for the market — while price regulation simulates the effect of competition in the market after the investment has taken place;

- the separate impact price and ROR regulation have on investment timing, suggests that the combination of the two forms of regulation, often referred to as hybrid regulation, may be beneficial for society;
- where there are rapidly decreasing costs of investing in an industry over time, it may be inappropriate for the regulator to just set any price that achieves the regulated fair rate of return;
- as the optimal access price requires both information about technological progress and underlying demand curve in an industry it may be difficult in practice to estimate. While regulators often use estimates of technological progress and levels of demand, they do not often have estimated demand schedules for an industry;
- assuming linear demand, a numerical example confirms the outcomes found throughout the course of this and the previous Chapter. In particular, it is shown that based on the regimes analysed here, where two-part access tariffs cannot be charged, the best outcome is achieved by having linear price-regulation of a competitive or ROR-regulated monopoly investor;
- using linear demand and a numerical example, FL cost regulation leads to later investment and induces a worse outcome for society than BL cost regulation. This appears to reinforce the results outlined in Chapter 5; and
- where there is FL cost regulation in an industry experiencing rapidly decreasing costs, the regulator may need to allow the investor to initially charge the unregulated monopoly price  $p_m$ . However, the certainty model used in this Section does not provide a case for an access holiday, as the access price must immediately decrease over time once the investment has been made.

As the framework used here assumes there is no uncertainty and that the investor is guaranteed the normal rate of return on the investment  $r$ , there are limits to the conclusions that can be drawn. Important issues, such as how the regulator should compensate the firm for the “truncation problem”, are not dealt with in the analysis here. However, it has been consistently demonstrated throughout the course of both Chapters that the results of the model, provide a simple formal way of capturing important ideas and concerns raised in the PC (2001a) and PC (2001b) reports on access regulation in Australia.

## A.7 Chapter 7 Appendix

### A.7.1 Deriving the Condition in Equation (7.3.6)

To establish the optimal condition that the access price for the monopoly investor  $p_x^*$  must satisfy in equation (7.3.6), the expression in equation (7.3.5) is simplified to give,

$$\left( \theta S'(p_x^*) + rCS'(p_x^*) + \frac{(\theta S(p_x^*) + rCS(p_x^*))r\pi'(p_x^*)}{\theta\pi(p_x^*)} \right) = 0$$

Multiplying the above expression through by  $\theta\pi(p_x^*)$ , and substituting in for  $S(p_x^*) = CS(p_x^*) + \pi(p_x^*)$  and  $CS'(p_x^*) = S'(p_x^*) - \pi'(p_x^*)$  yields,

$$\begin{aligned} \theta\pi(p_x^*)\theta S'(p_x^*) + \theta\pi(p_x^*)r(S'(p_x^*) - \pi'(p_x^*)) + (\theta CS(p_x^*) + \theta\pi(p_x^*) + rCS(p_x^*))r\pi'(p_x^*) &= 0 \\ \Rightarrow (\theta + r)(\theta\pi(p_x^*)S'(p_x^*) + rCS(p_x^*)\pi'(p_x^*)) - \theta\pi(p_x^*)r\pi'(p_x^*) + \theta\pi(p_x^*)r\pi'(p_x^*) &= 0 \\ \Rightarrow -rCS(p_x^*)\pi'(p_x^*) &= \theta\pi(p_x^*)S'(p_x^*) \end{aligned}$$

Rearranging the above expression,

$$\boxed{-\frac{CS(p_x^*)}{\pi(p_x^*)} \frac{\pi'(p_x^*)}{S'(p_x^*)} = \frac{\theta}{r}}$$

This is the optimal condition that was given in equation (7.3.6).

### A.7.2 Deriving the Outcome in Equation (7.3.13)

To establish the outcome in equation (7.3.13), the equation (7.3.6) is rearranged to give,

$$CS(p_x^*) = -\pi(p_x^*) \left[ \frac{S'(p_x^*)}{\pi'(p_x^*)} \right] \frac{\theta}{r}$$

and the total differential is then taken. This gives,

$$\begin{aligned} CS'(p_x^*)dp_x^* &= -\pi(p_x^*) \left( \frac{S'(p_x^*)}{\pi'(p_x^*)} \right) d\left(\frac{\theta}{r}\right) - \frac{\theta}{r} \left( \frac{S'(p_x^*)}{\pi'(p_x^*)} \right) \pi'(p_x^*)dp_x^* \\ &\quad - \frac{\theta\pi(p_x^*)}{r} \left[ \frac{\pi'(p_x^*)S''(p_x^*) - S'(p_x^*)\pi''(p_x^*)}{\pi'(p_x^*)^2} \right] dp_x^* \end{aligned}$$

$$\Rightarrow \left\{ CS'(p_x^*) + \frac{\theta S'(p_x^*)}{r} + \frac{\theta \pi(p_x^*)}{r} \left[ \frac{\pi'(p_x^*) S''(p_x^*) - S'(p_x^*) \pi''(p_x^*)}{\pi'(p_x^*)^2} \right] \right\} dp_x^* = -\pi(p_x^*) \left( \frac{S'(p_x^*)}{\pi'(p_x^*)} \right) d\left(\frac{\theta}{r}\right)$$

Rearranging the above equation in terms of  $dp_x^*/d(\frac{\theta}{r})$ ,

$$\frac{dp_x^*}{d\left(\frac{\theta}{r}\right)} = \frac{-\pi(p_x^*) \left[ \frac{S'(p_x^*)}{\pi'(p_x^*)} \right]}{CS'(p_x^*) + \frac{\theta S'(p_x^*)}{r} + \frac{\theta \pi(p_x^*)}{r} \left[ \frac{\pi'(p_x^*) S''(p_x^*) - S'(p_x^*) \pi''(p_x^*)}{\pi'(p_x^*)^2} \right]}$$

This is the expression given by equation (7.3.13).

### A.7.3 Deriving the Outcome in Equation (7.4.16)

To establish the outcome in equation (7.4.16), similar working is done to that used to show the outcome in equation (7.3.13). Therefore, equation (7.4.6) is rearranged to give,

$$CS(p_o^*) = -\frac{\theta}{r} \left( \frac{CS'(p_o^*)}{\pi'(p_o^*)} \right) \pi(p_o^*)$$

Taking the total differential of this expression yields,

$$CS'(p_o^*) dp_o^* = -\pi(p_o^*) \left( \frac{CS'(p_o^*)}{\pi'(p_o^*)} \right) d\left(\frac{\theta}{r}\right) - \frac{\theta}{r} \left( \frac{CS'(p_o^*)}{\pi'(p_o^*)} \right) \pi'(p_o^*) dp_o^* - \frac{\theta \pi(p_o^*)}{r} \left[ \frac{\pi'(p_o^*) CS''(p_o^*) - CS'(p_o^*) \pi''(p_o^*)}{\pi'(p_o^*)^2} \right] dp_o^*$$

Rearranging the above equation in the same manner that was done in A.7.2, yields the following expression for  $dp_o^*/d(\frac{\theta}{r})$ ,

$$\frac{dp_o^*}{d\left(\frac{\theta}{r}\right)} = \frac{-\left[ \frac{S'(p_o^*)}{\pi'(p_o^*)} \right] \pi(p_o^*)}{CS'(p_o^*) + \frac{\theta CS'(p_o^*)}{r} + \frac{\theta \pi(p_o^*)}{r} \left[ \frac{\pi'(p_o^*) S''(p_o^*) - S'(p_o^*) \pi''(p_o^*)}{\pi'(p_o^*)^2} \right]}$$

This is the outcome in equation (7.4.16).

#### A.7.4 Deriving the Outcome in Equation (7.5.12)

By evaluating the equations for consumer surplus, revenue and the derivatives at the optimal price  $p_x^*$ , and substituting the expressions into the optimal condition in equation (7.3.6), yields

$$\begin{aligned} &\Rightarrow -\frac{\frac{1}{2b}(a-p_x^*)^2}{\frac{1}{b}p_x^*(a-p_x^*)} \cdot \frac{\frac{1}{b}(a-2p_x^*)}{-\frac{1}{b}p_x^*} = \frac{\theta}{r} \\ &\Rightarrow \frac{\frac{1}{2}(a-p_x^*)(a-2p_x^*)}{p_x^{*2}} = \frac{\theta}{r} \\ &\Rightarrow \frac{a^2}{2} - \left(\frac{3a}{2}\right)p_x^* + p_x^{*2} = \left(\frac{\theta}{r}\right)p_x^{*2} \end{aligned}$$

Rearranging this,

$$\boxed{\left(1 - \frac{\theta}{r}\right)p_x^{*2} - \left(\frac{3a}{2}\right)p_x^* + \frac{a^2}{2} = 0}$$

This is the outcome in equation (7.5.12).

#### A.7.5 The Revenue and Consumer Surplus at $p_x^*$

Substituting the solution for the optimal access price  $p_x^*$  in equation (7.5.14), into the expressions for revenue and consumer surplus, yields the following outcomes for  $\pi(p_x^*)$  and  $CS(p_x^*)$ , given by equation (A.7.1) and (A.7.2).

$$\pi(p_x^*) = \begin{cases} \frac{a^2}{b} \left( \frac{\left(3 - \sqrt{1 + 8\left(\frac{\theta}{r}\right)}\right)\left(1 - 4\left(\frac{\theta}{r}\right) + \sqrt{1 + 8\left(\frac{\theta}{r}\right)}\right)}{16\left(1 - \frac{\theta}{r}\right)^2} \right), & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{2a^2}{9b}, & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (\text{A.7.1})$$

$$CS(p_x^*) = \begin{cases} \frac{a^2}{2b} \left( \frac{1 - 4\left(\frac{\theta}{r}\right) + \sqrt{1 + 8\left(\frac{\theta}{r}\right)}}{4\left(1 - \frac{\theta}{r}\right)} \right)^2, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{2a^2}{9b}, & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (\text{A.7.2})$$

#### A.7.6 Deriving the Outcome in Equation (7.5.21)

By evaluating the equations for consumer surplus, revenue and the derivatives at the optimal price  $p_o^*$ , and substituting the expressions into the optimal condition in equation (7.4.6), yields

$$\begin{aligned}
 &\Rightarrow -\frac{\frac{1}{2b}(a-p_o^*)^2}{\frac{1}{b}p_x^*(a-p_o^*)} \cdot \frac{\frac{1}{b}(a-2p_o^*)}{-\frac{1}{b}(a-p_o^*)} = \frac{\theta}{r} \\
 &\Rightarrow \frac{\frac{1}{2}(a-2p_x^*)}{p_x^*} = \frac{\theta}{r} \\
 &\Rightarrow \frac{a}{2} - p_x^* = \left(\frac{\theta}{r}\right)p_x^* \\
 &\Rightarrow \left(1 + \frac{\theta}{r}\right)p_o^* = \frac{a}{2}
 \end{aligned}$$

Rearranging this, the expression for an optimal price for the competitive or ROR-regulated monopoly investor is,

$$p_o^* = \frac{a}{2(1 + \frac{\theta}{r})}$$

This is the outcome for the optimal price in equation (7.5.21).

#### A.7.7 Revenue and Consumer Surplus at $p_o^*$

Substituting the solution for the optimal access price  $p_o^*$  into the expression for the revenue and consumer surplus, yields the following outcomes yields the following outcomes for  $\pi(p_o^*)$  and  $CS(p_o^*)$ , given by equation (A.7.3) and (A.7.4).

$$\pi(p_o^*) = \begin{cases} \frac{a^2(1 + 2(\frac{\theta}{r}))}{4b(1 + \frac{\theta}{r})^2}, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{3a^2}{16b}, & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (\text{A.7.3})$$

$$CS(p_o^*) = \begin{cases} \frac{1}{2b} \left( \frac{a(1 + 2(\frac{\theta}{r}))}{2(1 + \frac{\theta}{r})} \right)^2, & \text{when } \frac{\theta}{r} \neq 1 \\ \frac{9a^2}{32b}, & \text{when } \frac{\theta}{r} = 1 \end{cases} \quad (\text{A.7.4})$$

#### A.7.8 Deriving the Outcome in Equation (7.6.8)

Substituting the linear demand of  $q(p) = (a - p)/b$  into equation (7.6.7) yields,

$$\pi(p_t) = \pi(p_m)e^{-\theta(t-t_m)} \Rightarrow \frac{p_t}{b}(a - p_t) = \frac{a^2}{4b}e^{-\theta(t-t_m)}, t \geq t_m$$

$$\Rightarrow \boxed{p_t^2 - ap_t + \frac{a^2}{4}e^{-\theta(t-t_m)} = 0}$$

This is the outcome in equation (7.6.8).

#### A.7.9 Deriving the Outcome in Equation (7.6.9)

Applying the quadratic formula to solve equation (7.6.8),

$$p_t = \frac{a \pm \sqrt{a^2 - a^2e^{-\theta(t-t_m)}}}{2}, \text{ where } t \geq t_m$$

$$= \frac{a \pm a\sqrt{1 - e^{-\theta(t-t_m)}}}{2}$$

$$\Rightarrow \boxed{p_t = \frac{a}{2} \left[ 1 \pm \sqrt{1 - e^{-\theta(t-t_m)}} \right]}$$

This is the outcome in equation (7.6.9).



## CHAPTER 8: CONCLUSION

This thesis has employed a number of economic models to address important issues that have been highlighted in the access regulation of utility industries in several countries, including Australia. The analysis conducted throughout has examined the allowed fair rate of return and the method of asset valuation used by the regulator, and emphasised the impact these regulatory tools have had on investment and efficiency. In addressing efficiency, each of the three types — allocative, production and dynamic — identified by regulators, commentators, access seekers and access providers, has been considered.

Chapters 2 and 3 used the Averch and Johnson (1962) model to examine the efficiency of a monopoly subject to rate-of-return (ROR) regulation. Chapter 2 illustrated that a ROR-regulated and capital-subsidised monopoly generated similar outcomes, where the firm inefficiently over-capitalised in production. This equivalence was used to highlight a number of theoretical and potential policy implications in relation to production efficiency and investment. For example, it was shown that a monopoly subject to a lower fair rate of return, behaved in the same manner as a monopoly receiving a higher capital subsidy. This relationship between the fair rate and capital subsidy was explicitly derived in the alternative model of ROR regulation with shareholders.

Chapter 3 used the equivalence results to establish a formal general-equilibrium (GE) framework. This confirmed and extended existing welfare results on ROR regulation and the optimal fair rate. By focusing upon the production and allocative efficiency trade-off associated with ROR regulation, the Chapter also reconciled the different approaches used to illustrate the efficiency outcomes under ROR regulation; showed that the production inefficiency under ROR regulation could be illustrated by a Carlton (1979) production-deadweight-loss “banana”; and found the precise conditions where the introduction of the Yang and Fox (1994) property tax — a capital tax — could increase welfare.

Chapters 4 and 5 looked at the issue of forward-looking (FL) cost regulation. Chapter 4 provided an overview of FL cost regulation known as total element/service long-run incremental cost (TELRIC/TSLRIC), which was used to price access in the US and Australian telecommunications industry. This concluded that, while there had been consistent claims made that TELRIC/TSLRIC under-priced and over-regulated the industry, the predictions and forecasts of under-investment and network atrophy appear to be exaggerated. It highlighted limitations of certain criticisms of TELRIC/TSLRIC,

and suggested that, due to the different market structures in the telecommunications industries of the two countries, arguments from the US were not necessarily applicable in an Australian context.

Chapter 5 formally compared backward-looking (BL) and FL cost regulation on an existing investment, using a model which assumed there was a constant rate of technological progress. This found that the investor required a higher fair rate of return to be fully-compensated for the use of FL costs, and that the constant BL cost-based price generated a better outcome for society. The superiority of BL cost regulation suggested that the results highlighted by Guthrie, Small and Wright (2001) could be achieved without appealing to investment timing or uncertainty. There did appear, though, to be a case for adopting FL cost regulation in an industry subject to future deregulation.

Chapters 6 and 7 established a model that examined the effect of access regulation on the investment timing and efficiency of a competitive and monopoly investor. The analysis throughout both Chapters was conducted with reference to issues highlighted in two Productivity Commission reports on access regulation — PC (2001a) and PC (2001b). Chapter 6 formalised a definition of dynamic efficiency. It used this to show how inferences could be drawn about the benefits to society based on investment timing, and illustrated that a static allocative and dynamic efficiency trade-off could occur with a change in the usage price of a two-part access tariff. The Chapter also highlighted that the outcomes for the ROR-regulated monopoly investor were identical to those of the competitive investor, and that, similar to Gans (2001), the socially-optimal outcome could be achieved with a two-part access tariff. This socially-optimal two-part access tariff was both allocatively and dynamically efficient.

Finally, Chapter 7 demonstrated that the linear access price for investors that maximised the benefit to society was neither dynamically nor allocatively efficient. It was an example of a second-best efficient price. The separate effects that price and ROR regulation had on the investor were detailed, and a numerical example illustrated that price regulation of the competitive or ROR-regulated monopoly investor, generated the best outcome for society where two-part access tariffs could not be used. The comparison of BL and FL cost regulation of the monopoly investor reinforced the results from Chapter 5.

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